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ABSTRACT

A study of the behavior of children working on mathematics drill and practice on one of four Israeli computer-assisted instruction (CAI) systems--Mashov, Semel, Tapuach 1 and 3, or Toam 2--was carried out via observations in a sample of 21 computer rooms throughout Israel, and in a computer room operated by research staff. These observations focused on: (1) broad activities of pupils such as engagement with the computer, with the operator, with another pupil, or with auxiliary material; (2) problem content and pupil-computer interactions during a single problem; and (3) children having difficulties, which involved unstructured conversation between the students and the observer. It was found that the systems were well run and efficiently utilized, and that students tended to work diligently and were satisfied with their computer room experiences. Nevertheless, programs could be improved by reducing opportunities for non-constructive guessing and providing response-specific feedback. A list of 26 references is provided, as well as lists of both Hebrew (bibliographic citations are in English) and English publications of the National Council of Jewish Women Research Institute for Innovation in Education at the Hebrew University of Jerusalem. An abstract of this report is provided in both Hebrew and in English. (Author/MES)

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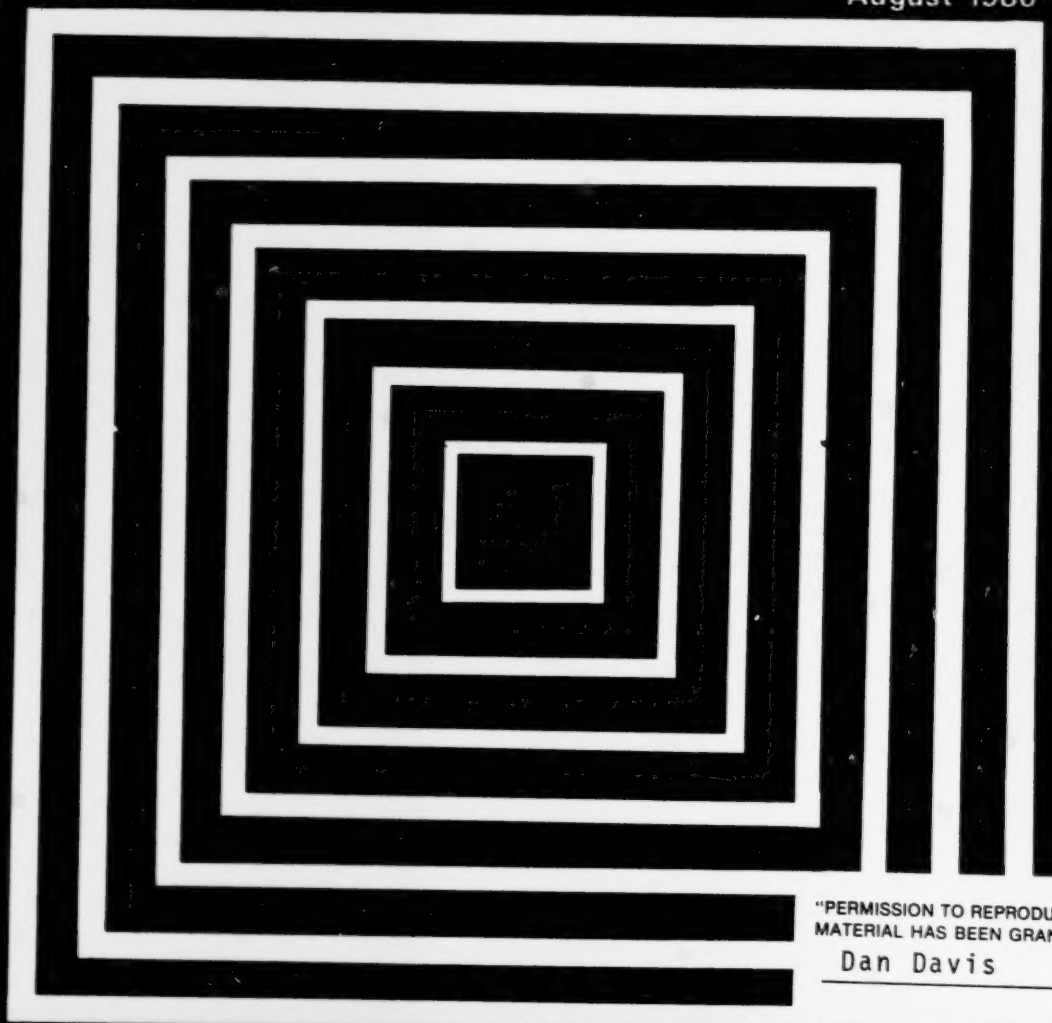
OBSERVATIONS IN SCHOOL COMPUTER ROOMS

DAN DAVIS, SHLOMO VINNER
TERRI FINKELSTEIN, CHANA REGEV

Publication No. 111

August 1986



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Director: Professor Chaim Adler Tel: 02-882015
Assistant Director: Ms. Lorraine Gastwirt Tel: 02-882016
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We wish to thank school principals and staff for their cooperation. Special thanks are due to Professor Shlomo Kugelmass (then Chief Scientist of the Ministry of Education and Culture), Nora Cohen, and Yair Levin of the Ministry of Education and Culture for their encouragement and support in various aspects of the research.

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Observations in School Computer Rooms

Dan Davis, Shlomo Vinner
Terri Finkelstein, Chana Regev

Abstract

In a series of observations, the behavior of children as they worked in math drill and practice on one of four Israeli systems (Mashov, Semel, Tapuach and Toam) was examined. The observations were carried out in two contexts: one, a sample of 21 computer rooms throughout Israel, and two, a computer room in a Jerusalem elementary school which was operated by our research staff. Three types of observations were carried out. One focussed on the broad activities of pupils, e.g. engagement with the computer, with the operator, with another pupil, or with auxiliary materials. The second type focussed on the content of a problem and on pupil-computer interactions during a single problem. The third type of observation was made on children having difficulties and involved an unstructured conversation between the observer and the pupil.

In general, we found the systems to be well run and efficiently utilized. Also, children tended to work diligently and were satisfied with their computer-room experiences. There is no doubt that the computer has succeeded in increasing time on task, especially for children in disadvantaged schools, and we attach great importance to this. But, however gratifying it is to see children sitting quietly and working, this in itself, is not enough. The systems we have observed provide only a start toward developing educationally effective computer curricula. They are largely hit or miss in their analysis of pupil responses and in their provision of feedback to both teachers and pupils. They tend to be rigid in their structuring and phrasing of questions which allow children to successfully utilize surface cues to get correct answers. Together, these encourage guessing strategies which defeat the purpose of the drill.

Recommendations for improving the programs include reducing opportunities for non-constructive guessing and providing response-specific feedback.

תצפיות בחדרי מחשבים

דן דיוויס, שלמה וינר
טרי פינקלשטיין, חנה רגב

תמצית

במחקר זה נבדקה התנהגות תלמידים בעת עבודתם עם אחת הארבע מערכות תירגול ואימון בסיוע מחשב (משו"כ, סמ"ל, תוא"ם ותפו"ח). הבדיקה נעשתה במהלך תצפיות שנערכו בשתי מסגרות: א) מדגם של 21 בתי-ספר ברחבי הארץ, ב) חדר מחשבים בבית-ספר יסודי בירושלים שמופעל על-ידי צוות המחקר. נערכו שלושה סוגי תצפיות: תצפית פעילות שההתמקדה בפעילויות התלמידים בזמן התירגול; תצפית תוכן שהתמקדה באינטראקציה מחשב-תלמיד במשך הצגת ופתרון בעיה בודדת; ותצפית מתערבת שנעשתה על תלמידים שהתקשו בפתרון בעיה וכללה שיחה בין הצופה לבין התלמיד.

נמצא כי בדרך-כלל המערכות מופעלות באופן סדיר ומנוצלות רוב שעות הלימודים. תלמידים היו מרוכזים בעבודה והביעו שביעות רצון מעבודתם עם המערכות. המימצאים לגבי מידת הריכוז של התלמידים בזמן עבודתם עם המערכות (TIME ON TASK) היו מרשימים, במיוחד לגבי תלמידים הלומדים בבתי-ספר טעוני-סיפוח.

אולם, למרות שנעים מאוד לראות ילדים יושבים בשקט ועובדים, אין די בכך. התירגול בסיוע מחשב נמצא היום רק בתחילת הדרך של פיתוח לומדות חינוכיות יעילות והמערכות שנבדקו במחקר זה עדיין אינן אופטימליות. ההיזון-החוזר הניתן לתלמידים על-ידי המערכות הוא בעיקר דיכוטומי (נכון/לא נכון) ואינו מהווה אינטראקציה חינוכית רצויה עבור התלמיד. מבנה מערכות התירגול בדרך כלל נוקשה מאוד, מעודד במקרים רבים תירגול אוטומטי ואף ניחוש - ללא הבנה, ותורם לעיתים לתיסכול בלתי נחוץ אצל התלמידים.

המלצותינו לשיפור מערכות התירגול דנות בהקטנת ההזדמנויות לניחוש, כמתן היזון-חוזר ספציפי לטעויות של תלמידים, ובשיפור איכות האינפורמציה על ביצועי התלמידים הניתנת למורים.

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1. INTRODUCTION

Israel is fully committed to the introduction of computers into schools. This is demonstrated by the fact that virtually all 600 high schools and about one third of the 1,600 elementary schools are now using computers in one form or another. Also, another third of the elementary schools are actively working to acquire computers. As schools are clamoring to buy computers and courseware companies are clamoring after schools the development of courseware is still in its infancy. Changes are being made in recently developed programs while new ones are being created as quickly as possible. In addition, as the hardware becomes more sophisticated so does the capability to develop more sophisticated software and courseware. For example, the sophistication of software possible on the IBM-PC is not possible on the Apple-IIE. However, software sophistication has not kept up with hardware developments leading to situations where powerful computers are little more than "electronic page turners" (a term phrased by computer critics). In this dynamic milieu the educational system, which is under pressure to incorporate computers into the school system, is often put in the position of running after the technological developments. In Israel, where the Ministry of Education funds to a large extent the aquiring of computers in disadvantaged schools and controls, post hoc, which hardware is acceptable, the situation becomes trying at best and inefficient at worst. For example, the development of courseware using an authoring language on the Atari computer is funded by the Curriculum Department of the Ministry of Education, yet today, the computer committee of the Ministry will not fund a school that wishes to buy Atari computers. A solution will be found but the question remains, when and at what price.

Because of this dynamic and to a large extent confusing situation, we as evaluators are put in a difficult position. On the one hand, as we are evaluating systems, improvements and additional courseware are being developed. At the same time the Ministry is creating policy in an attempt to adapt to the changing realities of the state of the art. Some of the

programs we are investigating may soon be obsolete. However, this does not imply that later an obsolete system cannot be revised, improved, and brought back to the living. In addition, evaluation of current systems may provide valuable information for the development of new ones. We have embarked on this research with this in mind.

In this report we investigate activities in school based computer rooms of three major Israeli systems (Mashov, Semel and Toam; also a fourth, Tapuach, is included in some of the comparisons). In addition, in two related studies, we are examining the effect of computer based math drill and practice on math achievement. In the first we compared the effects of computer drill and practice versus utilization of a math expert for the same cost. The results have been analyzed and a report submitted to the Chief Scientist of the Ministry of Education. We relate to these in our discussion. In the second study, we are comparing the effects of three systems. As of June 1985 children will have been working a year and a half with the programs and will have been tested six times. The results should be analyzed by October 1986.

In this report we do not investigate effects on achievement and those who hope to see specific recommendations of one system versus another will be disappointed. It is obvious to us that the development of courseware is in its infancy and we view this evaluation as formative rather than summative. We hope that the information presented here will be used to improve present computer based instructional systems as well as provide valuable information for the development of new ones.

2. BACKGROUND

1. A DESCRIPTION OF SCHOOL COMPUTER ROOMS AND THEIR OPERATION

The computer room, as implied in its name, is a room set aside by the school for the computers.* It is different from the regular classrooms in the school: the electrical wiring of the room is designed to supply additional power and safeguards; the room is protected by a "rav-bareach" (anti-burgler) door and bars on the windows. Because of the hot climate, there is often air-conditioning, required for Toam and optional for the other systems. Curtains, to reduce the glare on the screen, are required for Toam and optional for the other systems. Wall to wall carpeting is also a required addition for Toam, and may or may not exist in computer rooms using the other systems.

These are not trivial components, for as well as the additional expenditures (albeit, one time expenses) they generally enhance an atmosphere of an important, special room in the eyes of the staff and in the eyes of the children. This goes beyond the usual increase in status resulting from possession of computers.

In all computer rooms observed, the children work individually, one child per station (defined as a terminal or computer with monitor and keyboard). Problems appear on the monitor's screen and the pupil answers using the keyboard.

In the lessons observed, groups of children used the computer room at a scheduled time (half the class, the whole class, etc., depending on the number of terminals in the school). Usually the children worked on the same subject during the lesson.

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* In four Toam schools there is no special room for computers, rather, terminals are distributed among the classrooms and incorporated in individualized instructional frameworks. However, this mode of utilization is still rare.

The systems observed consisted mainly of courseware intended for the drill and practice of material previously learned in the classroom. The distributors all suggest 20 minutes of drill and practice in math twice a week (usually the same for the other subjects available). Most of the lessons observed were 20 minutes long. We also observed lessons of 40 to 50 minutes during which the pupils worked on one subject continuously or switched subjects after 20 minutes.

Ideally, each pupil begins to work with the program at his appropriate level, determined by the teacher or by the computer. The pupil progresses at a rate which depends on his performance. Each system has its own criteria for advancement. The staff member present while the children are working in the computer room may be their homeroom teacher, their teacher of the subject being drilled or a staff member responsible for the running of the computer room. The staff member present is responsible for the technical running of the room, maintaining discipline and helping the children when necessary.

2. OVERVIEW OF THE SYSTEMS

In a prelimenary stage of this research, a survey was carried out in which the major computer systems were described in detail (Davis et al, 1983). The systems were similar in that they generally focused on providing drill and practice in math, reading or language and tried to reflect the curriculum of the Ministry of Education (although, none covered all of the topics outlined in the curriculum). All were designed to be used as review to material taught in the classroom. All provided reports to the teacher on pupil progress, and in all cases the children worked individually, each progressing at his/her own pace. Despite their surface similarities, striking differences existed between the systems on aspects such as the format in which the material is presented, when feedback is presented and motivational tools. Because of these seemingly subtle yet important differences between the systems, we feel it necessary to briefly describe each of them, summarize the findings of the survey, and highlight their

differences before we present the findings of our observations, for, to a certain extent, our findings will be examined and discussed in the light of the exclusiveness of each system.

Mashov

Mashov is a CAI system adapted for use on Atari micro-computers. The system is designed to work as a network, utilizing an auxiliary memory which contains the software and courseware. The standard system consists of 16 stations. The system was developed at the Ben Gurion University of the Negev under the auspicies of the Ministry of Education. The developers focused on the needs of the disadvantaged children learning in conventional classroom settings and the courseware was designed to match the curriculum of the Ministry of Education. Mashov has since been incorporated into the commercial company **Edunetics**. Courseware in Mashov exists for the following subjects:

4th and 6th grade math
5th and 6th grade reading comprehension and language usage
5th to 7th grade English
5th grade religion

The courseware in math is designed as lessons and progression through the lessons utilizes branching as a function of student performance.

The developers emphasize teacher involvement and promote an accompanying learning room as an integral component of the system. Here, the teacher works with half of the class while half are working in the computer room. Supplementary work sheets to be used in the learning room are provided. The focus of **Edunetics** today is their recently developed authoring language which is used to develop lessons and tutorials.*

There are currently 27 elementary schools and 3 high schools using **Mashov**.

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* The authoring language of **Edunetics**, Leader, is now being used by the curriculum department of the Ministry of Education, where teachers in writing teams use the language to develop courseware.

Semel

Semel is adapted for use on Commodore microcomputers and is designed to work as a network with 2 to 10 computers linked to a double disk drive. The system is flexible as to the number of stations used, there can be as few as 2 stations and in one school we visited there were 40 stations. **Semel** was developed by the teachers of Kiryat Shmona under the guidance of their Municipal Education Department. It is a "grassroots" project that grew out of an attempt to design an effective diagnostic and testing tool to accompany the individualized developmental math program used in Kiryat Shmona.* Today **Semel** is jointly funded by the Ministry of Education and The Institute for Teaching Aids (Hamachon Liemzai Hora'ah). All the development of courseware is funded by the Ministry and guidance is given within the framework of the Institute. Courseware exists for the following subjects:**

1st to 8th grade math
3rd to 9th grade language usage
6th and 7th grade English
7th and 8th grade history
7th and 8th grade oral tradition of the Torah
Educational games in math
Enrichment programs for cognitive development

The courseware in math is designed as a linear progression through the different strands (i.e. addition, subtraction, multiplication etc.) and the other subjects are designed as modular units.

The developers emphasize the necessity of teacher involvement and have developed a system open to teacher intervention. For example, teachers are

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* Developed by Tzipora Katz.

** The courseware in math and reading includes material taught from 1st grade. The developers, however, suggest that the use of computers start only from 4th grade. The material from the lower grades is intended for use with the weaker students.

able to change many parameters in the courseware. The teachers themselves can program lessons (within the confines of existing models at their disposal).

Semel has also developed an authoring language, Magic, which enables courseware to be developed that utilizes graphics and color. Using Magic Semel is developing courseware in which types of mistakes are distinguished and are used to channel the students through remedial exercises. The Ministry of Education is also using Magic to develop courseware.

There are currently 152 elementary schools and 6 high schools using Semel.

Toam 2*

Toam 2 is a CAI system adapted for use on a Dec mini-computer with 16 to 32 terminals. Toam is a project of the Center for Educational Technology, which is supported by the Rothchild Foundation as a public non-profit company in cooperation with the government (the Board of Directors of the Center for Educational Technology includes key officials from the Ministry of Education). The Center for Educational Technology developed the terminals specifically for use with Toam and the content is based on a translation and adaptation of Suppes's drill and practice program. The system is intended to accompany students studying in a conventional classroom setting, although the distributors recommend using Toam with individualized math and reading programs, also developed by the Center for Educational Technology. Courseware exists for the following subjects:

2nd to 7th grade math
2nd to 7th grade reading comprehension
5th to 7th grade English

* An older system, Toam 1, which is now being phased out, is a CAI system for math drill exclusively. The newer expanded system, Toam 2, is described here and includes the material from Toam 1.

The courseware is designed as a linear progression through the different strands in the programs, each student at his own pace as determined by performance.

In addition to the courseware available on Toam 2, schools can buy additional software and hardware (the DEC RSTS\E operating system and full keyboards). These allow the use of additional courseware (some of which must be bought separately):

Computer Based Accountancy System
(in use in vocational and technical high schools)

Computer languages
(Basic Plus, Pascal, cobol, Fortran and Assembler)

Educational Games

Hebrew typing course using the touch typing (blind) method

Structured Mixed Initiative Learning Environment - SMILE
(a program used in conjunction with courses in electricity in 10th grade and in the army. Students have an information retrieval base at their disposal which can be used to clear up difficulties as well as to progress more rapidly.)

Task training management program
(in use in the army)

The focus of Toam today is the continual improvement and development of courseware. For example, the integration of graphics in their new courseware and the development of geometry for elementry and high school.

Toam is the oldest CAI system in Israel and the most predominently used. Currently there are 230 elementary and 16 high schools using Toam.

Tomer

Tomer computers distributes Tapuach courseware intended for use in the school system. Tapuach is adapted for use on Apple micro-computers where

each computer is attached to a disk drive and works as an independant learning station. The system can also be operated as a network with the addition of an external memory (Corvus). The system is flexible as to the number of stations used.

Tapuach consists of two main programs. The first program, **Tapuach 1**, is a translated version of an American commercial math drill and practice program put out by Milliken*. The second program, **Tapuach 3**, has drill and practice for math and other subjects as well as an authoring language for developing courseware (An older program, **Tapuach 2**, has been incorporated into **Tapuach 3**).

Tomer Computers is based in Haifa and recently opened an office in Tel Aviv. The initial development and translation of **Tapuach 1** was done in cooperation with the computer center of the religious youth village "Kfar Chasidim". Courseware exists in the following subjects:

Tapuach 1

1st to 7th grade math

Tapuach 3

2nd to 6th grade language comprehension

7th to 9th grade English

7th to 12th grade mathematics

Math games

The courseware is designed as a linear progression through the programs. **Tapuach** math is different from the other computer systems in that the student works on one strand exclusively (until the disk is physically changed by the operator). Each teacher decides how many strands each child will work in each session.

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* Milliken has informed us that there is no authorized use of their materials in Israel. Also, the version used by Tomer is apparently one which has been taken off the market by Milliken and replaced. Tomer, in reply, stated that as of the 1985-1986 school year they have replaced the Milliken materials with a version of their own.

The focus of Tomer today is the continued development of courseware using their authoring language, Tapuach 4. Any school which buys Tapuach courseware may receive the authoring language under the condition that all courseware developed in the school is officially the property of Tomer. Tomer reported that 200 courses have been developed on Tapuach 4. We have not reviewed this material.

Tomer is also developing a newer version of their authoring language, Tapuach 5, which will include animation. Both Tapuach 4 and Tapuach 5 are based on Apple's pro-mouse which is a drawing device.

Since Tomer is also a distributor of Apple computers, a school may buy computers and Tapuach 1 and use the computers for programming lessons only. Therefore it is difficult to estimate the number of schools using Tapuach courseware.

3. HIGHLIGHTING THE DIFFERENCES

In this section various differences between the math programs of the four systems are described,* differences which potentially affect the manner in which the system is used in the school and the way in which the students work with the programs. Five topics are discussed; initial placement of students in the program, presentation format, teacher control and the format of answering the problems and feedback.

Initial placement

Except for Toam initial placement of students in the program is determined by the teacher. In Toam each pupil begins by working with a diagnostic program consisting of the first 12 lessons. The pupil's performance determines the initial placement in each of the strands of the math program.

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* In this section we refer to Tapuach 1 (Milliken) exclusively.

Presentation format

Mashov is designed as sequential lessons. For example, the lesson on the multiples of 5, 10 and 25 is followed by multiples of 11 and 12. The pupil works through the lesson and then moves on to the next topic. **Mashov** uses color and graphics, and examples are given, usually at the beginning of a new topic. Problems are presented in various formats, producing a varied and colorful presentation.

The courseware in **Semel** is organized into strands (addition, subtraction multiplication, etc.). The items in each strand are grouped according to their complexity and progression through the strand is based on increasing levels of difficulty. The pupil receives a series of problems from one strand and then receives a series of problems from a different strand. Therefore, during one sitting, the pupil works on problems from a number of different strands. The presentation of the problems is varied. Some of the time only one problem appears on the screen and some of the time completed problems stay on the screen as a new one appears until the screen is full. Existing courseware does not use color or graphics, but these features are in courseware currently being developed. A standard feature of the drill is a variety of educational games that the pupil automatically receives in the middle of the lesson.

Toam courseware is organized into strands and difficulty levels within each strand. The pupil receives problems from different strands during one lesson. Each new problem presented is from a different strand and only one problem appears on the screen at a time. The keyboard for **Toam** was developed at the Center for Educational Technology and is a scaled down to consist only of the numerals 0 to 9 and the symbols for 'greater than', 'less than' and 'equal'. **Toam** does not use color or graphics in existing programs, but these features are used in courseware being developed.

In contrast to **Toam** and **Semel**, the pupil working in **Tapuach** receives problems from one strand continuously (each strand is on a separate disk).

The teacher decides how many strands the pupil will work in and for how long. If the teacher so desires, the pupil can work exclusively on one type of problem over an extended period of time or can change the strand during an individual lesson but the program can not present problems from different strands automatically. Only one problem appears on the screen at a time, and graphics is used in feedback concerning the 'correctness' of answers. Color is used randomly.

Teacher control of parameters

In **Mashov**, the teacher may determine the order of presentation of the lessons and may change the order as the year progresses. The teacher may place a pupil through a lesson again.

In **Toam**, the teacher may move a child up or down within a particular strand and may extend the amount of alloted time for response. The teacher may not control which strands the pupil receives problems from, nor indicate an upper limit within an individual strand. This could be relevant, for example, if the teacher does not want the pupil to practice material not yet covered in class.

In **Semel** many parameters are open to the teacher: placement in the strands, when and how many strands are to be presented, the closing and opening of strands at any point during the year, long range and short range planning of practice sessions. As in **Toam**, a teacher using **Semel** may not indicate an upper limit in the individual strands.

In **Tapuach**, each strand is on a separate disk and all the above options are open to a teacher. Teachers using **Tapuach** may indicate upper limits within strands.

Format of answering problems

In **Semel** and **Mashov** the pupils are not timed and answer the problems at their own pace. The pupil may work out the problem on pencil and paper,

and only the final answer is entered and judged for 'correctness'. (In a few lessons in Mashov, in which a specific manner of solving problems is the topic of the lesson, it is necessary for the pupil to do the intermediate stages of the problem on the screen).

In Tapuach the option of penalizing students who do not answer in an alloted time exists, yet in talks with the distributor and in our observations no use of the option was noted. For problems which involve partial products, (e.g., multiplication of two digit numbers or long division) the system is flexible as to whether the pupil does the intermediate stages on the screen, in his head or on paper. When the pupil works out the intermediate stages of the problem on the screen, only the final answer is judged for 'correctness'. Also when working out the intermediate stages on the screen the cursor is automatically placed in the correct position. For example, when multiplying the tens of a two digit number the cursor automatically moves one space to the left. In this manner, partial product alignment is given and eliminates the possibility for the pupil to make this mistake. Research on children's mistakes has found partial product alignment to be one of the most common (see Reisman, 1972).

The format in which the pupil works out the problem is most distinctly different in Toam from the other systems. Pupils are penalized if the problems are not answered in the alloted time. This is in accordance to Toam's policy of maximized utilization of time. In addition, the pupil works out all intermediate stages on the screen and partial product alignment is given by the cursor. Also each numeral entered by the pupil is judged for 'correctness' and when the numeral is incorrect the mistake quickly disappears. Thus, the pupil does not control the timing of the evaluation of his answer and when he enters an incorrect digit he is essentially told where his mistake is, is given the opportunity to correct it and then continues from where he is in the problem to completion. In this manner the child receives feedback as to the 'correctness' of each

numeral entered and cannot complete the problem incorrectly. In the other systems the pupil solves the problem in its entirety. Partial product alignment is done by the pupil, thus allowing him the opportunity to make this common mistake (unless the pupil is working in Tapuach and desires to work out the problem on the screen). The pupil can change his answer and only when the pupil is finished and states so by pressing the return key does the computer evaluate the answer. Also, if a pupil has made a mistake, he must do the problem over in its entirety, with no cuing from the computer as to where the mistake was. Therefore, the trials given a child to correct an incorrect answer are qualitatively different in Toam than in the other systems. In the other systems, three trials refer to three separate attempts to solve the problem in its entirety. In Toam the pupil is given three chances to answer correctly, but the three trials relate to solving the problem in its entirety only once.

Another striking difference between Toam and the other systems is whether or not the pupil uses paper and pencil to solve the problems. In the other systems the pupil may decide to solve the problem on paper first. In all schools we visited using Toam, the children were not allowed to use paper and pencil (at any grade level and for any strand) and we were told that this is Toam's policy. When asked, Toam replied that their definition of difficulty level within strands is based on the premise that the children do not use pencil and paper.

Feedback

The 'correctness' of the pupils' answers in three of the systems, Mashov, Semel and Toam, is stated with the words 'right', 'correct', etc., with little or no variation. In Tapuach the feedback is varied in size, content and utilizes graphics. For example, when the student answers correctly the system replies with a smiling face or a printed 'correct' which fills up the entire screen. Similarly, when the answer is incorrect the system replies with a large 'no' or a crying face which takes up the entire screen. In all the systems the feedback is dichotomous, correct-incorrect,

except for a few English lessons of Semel in which a forgotten capital letter is not considered a mistake and a reply to that effect is given to the pupil.

The display of incorrect responses differs among systems. In **Mashov** when the answer is incorrect, the computer replies 'incorrect', and after a few seconds the incorrect answer disappears. In **Semel**, when the answer is incorrect the computer replies 'incorrect', the incorrect answer is highlighted for a few seconds and then disappears.

In **Toam**, an incorrect answer disappears so quickly that in many of our observations we found it difficult to distinguish what, in fact, was answered. In meetings with the distributors of **Toam**, the question was raised as to whether the philosophy of the system is not to let the pupil see his mistake. **Toam** explained that this is in fact part of a policy maximizing the utilization of time, and in their opinion, the incorrect answer stayed on the screen long enough (.5 seconds) for children to see.

Only in **Tapuach** does the incorrect answer remain on the screen. When an answer is incorrect, the computer replies to that effect but the screen does not change until the pupil presses the return key. This allows the pupil to scrutinize his mistake (this is not to imply that all pupils do this, but the ability to do so exists).

With regard to progress reports, in both **Toam** and **Tapuach** the pupil is given a report at the end of each lesson consisting of how many problems he received and how many he answered correctly (lessons in both **Toam** and **Tapuach** consist of 10 minutes but usually the pupils work 20 minutes per sitting).

In **Mashov** the pupil receives a grade at the end of each lesson. Since lessons may last more than one session, the meaning of the grade may not be clear. For example, in one case, five minutes into a session, the computer

informed the pupil - 'You have completed this part of the lesson, your grade is 73' - and yet in the 5 minutes that the pupil worked he did not make a mistake and did not understand why he received a 73.

In Semel the pupil does not receive any grade or summary of how many problems were answered correctly. Grades did exist in the English program but teachers using the program requested that it be eliminated due to frustration of the students when they received a low grade. The only progress report that the pupil may receive is in the form of a letter from the computer which utilizes a friendly and encouraging language to inform the pupil where he is in the different strands. He may be informed that he is progressing quickly or that the material is not clear to him yet. Also, he may be directed to turn to the teacher for explanation. It is up to the operator and school policy as to how often the children receive the report.

3. INSTRUMENTS

DEVELOPMENT OF THE OBSERVATIONAL INSTRUMENTS AND PILOT STUDY

The purpose of the observations of the computerized drill and practice programs was to describe and quantify the work patterns of the children using the different programs. We decided to focus on the motivation and concentration of the children while working and on their interactions with the computer. With these objectives in mind, we examined existing classroom observational instruments. Due to the different characteristics of the computer room in comparison to the regular classroom, existing observational instruments did not fit our needs. In the end, it was necessary to develop our own, in part utilizing components of three existing ones: CISSAR (Stanley and Greenwood, 1981) for individualized observations in the classroom, an observational instrument for the biology laboratory (Friedler, 1984), and the Student Activity Profile (Honigan and Stephens, 1969) for analyzing student functioning in an individualized instructional setting. Two instruments were developed for the observations in the computer room and are described below.

1. DEVELOPMENT OF THE "ACTIVITIES" INSTRUMENT

(March 83 - February 84)

The first observational instrument focused on the overall work patterns and motivation of the students while working with the computer programs. The initial development took place in 6 schools using **Mashov, Semel, Tapuach, Toam 1** and **Toam 2** programs. The initial instrument was a crude mix consisting of the CISSAR categories of behavior and the Friedler format of observation. In brief, we categorized behavior as on-task, inappropriate and other categories specific to the work with computer programs. The format of observation was to observe each student for 5 minutes, recording a behavior every 10 seconds. (We tested recording behaviors every 5, 7, 10 and 15 seconds. 10 seconds was found to be optimal.)

During this stage of the field development of the instrument, we ran into two major problems. The first problem related to sampling of children, and the second to the obtrusiveness of measurement.

Initially we observed each pupil for 5 minutes but the lesson usually lasted only 20 minutes and the pupils did not arrive at the same time nor did they finish at the same time. This created problems of sampling since it was not possible to observe all the children in a given lesson, especially in computer rooms with 32 terminals. At this stage we changed the format of observation (based on Honigan and Stephens) in which we noted the distribution of behaviors over all students rather than on individual students. This was achieved by observing the behavior of the pupil at the first station, coding it, moving to observe the pupil in the next station, noting it and so on until the end of the lesson. In this fashion, all children were observed and we focused on recording an accurate picture of the distribution of behaviors within one lesson.

The solution to the first problem solved the second as well, which concerned the obtrusiveness of the observations. When we observed children for 5 minutes consecutively we noted a change in the behaviors exhibited. For example, it was noted in some cases that pupils refrained from chatting with their neighbors while being observed and resumed doing so when the observer moved away. When the observer moved continually around the room the observation itself was less obtrusive. In addition, we observed two pupils ahead of the pupil we were behind and therefore observed more natural behaviors.

We tested this modified version of the **Activities** instrument in 26 **Toam** and **Mashov** lessons.

After coding the observational data gathered we ran a preliminary analysis. Based on the analysis two changes were made:

1) Low frequency categories with high similiarty were combined reducing the number of categories from 48 to 22.
2) A timing device was made in which a red light blinked. The timing between blinks was changeable from every 3 seconds to every 15 seconds. The pace of observation was tested and 5 seconds was decided on. In this manner, all behaviors were noted at the same pace, regardless of observer, lesson, school or computer system.

2. DESCRIPTION OF THE ACTIVITIES INSTRUMENT

As previously described, this was designed to describe and quantify the work patterns of the pupils, their motivation and concentration. The instrument is divided into 7 categories:

(1) **Interaction with the computer**

This category was noted when the child exhibited eye contact with the screen and/or was using the keyboard. This included the child logging-in, reading directions, reading the problem or answering the problem.

(2) **Interaction with the operator**

We distinguished four types of pupil-operator interactions:

a. The interaction concerned the material being drilled.
b. The interaction concerned a technical or managerial matter.
   For example, this was coded when a pupil asked where the multiplication key was.
c. The interaction was of a disciplinary nature.
d. Other
   This category was noted when the interaction did not have to do with one of the categories above or was not identified.

(3) **Use of auxiliary materials**

This category was noted when the pupil was solving problems on paper, getting out a pencil or recording his progress.

(4) **Interaction with other pupils**

We distinguished four types of pupil-pupil interactions:

a. The interaction concerned the material being drilled.

b. The interaction concerned a technical or managerial matter.

c. The interaction was inappropriate to the task at hand.

This category was noted when the pupil was typing on another pupil's keyboard, fighting with another pupil, etc. This category was noted only when the interaction taking place was between two pupils to differentiate it from out and out chaos among a group of pupils or the entire class. In this case the category 'inappropriate behavior' was noted (see category 5 below).

d. Other.

This category was noted when the interaction was not readily distinguishable, although the observers attempted to note one of the categories above whenever possible.

(5) **Inappropriate behavior**

This category was noted when the pupil exhibited inappropriate behavior: talking out loud, wandering around the room, or behaving in some other disruptive or agressive manner. This category was also noted when more than two pupils were behaving inappropriatly.

(6) **Emotive behaviors**

Three behaviors were identified as emotive behaviors:

a. Positive

This was noted when the pupil overtly reacted positively to the program. For example, when a pupil answered correctly and threw his hands up in a victory sign and shouted 'I did it', or called to the teacher to come and see his grade, etc.

b. Negative

This was noted when the pupil overtly reacted negatively to the program. For example, the pupil exclaimed 'this computer is dumb' or 'I don't understand what this computer wants from me' or fell back into his chair groaning, etc.

c. Self-stimulation

This category was taken from the CISSAR observation. It was noted when the child exhibited signs of nervousness, rocking back and forth rapidly in his chair, etc.

Due to the subjectivness of identifying these three categories they were noted only when the child did not exhibit any other accompanying behavior. If the child was rocking back and forth rapidly in his chair and solving the problem on paper, the category "using auxiliary materials" was recorded and not "self stimulation".

(7) Other

There are five behaviors included in this category:

a. Looking around

The pupil was staring into space, at his neighbor's screen, at two other pupils fighting, etc.

b. Looking at the observer

This category was included in order to estimate observer interference and is discussed in more detail in section 4.

c. Hand raised

The pupil was waiting for the teacher.

d. Discipline

This category was recorded when the teacher was disciplining the entire class and the pupil was listening.

e. Playing a game

This appeared only in Semel where an educational game is an automatic part of the drill. This category was later included as an on-task behavior.

f. Waiting

The pupil was waiting for the program to continue.

If it was impossible to distinguish a child's behavior, the observer recorded 'not clear.' This rarely occurred. In addition, when a station had no child working at it, we noted whether it was simply not being utilized at the time or whether it was malfunctioning.

3. DEVELOPMENT OF THE "PROCESS" INSTRUMENT

The second instrument is concerned with problem content, pupil response and computer feedback. The **Process** instrument was relatively easy to develop since we were usually able to record exact descriptions without categorizing behaviors or problems. As in the **Activities** observation, the observer moved from station to station to avoid obtrusiveness. At each station the observer waited until the appearance of a new problem on the screen and recorded the problem, pupil response, computer feedback and any other behavior exhibited until the problem was completed. The observer moved away, made additions and comments when relevent and moved to the next station, continuing in this fashion until the end of the lesson.

The pace was controlled by the computer-child interaction in that the pupil was observed from the beginning of a problem to its completion.

4. DESCRIPTION OF THE PROCESS INSTRUMENT

As previously mentioned, the content of the child-computer interaction was observed. The observation consisted of noting exactly what appeared on the screen, the pupils response, the computer response, etc., until the problem was completed. For this purpose a coding sheet was designed that was partitioned into 6 columns and was filled in as follows:

(1) Station number

The station number was noted mainly for administrative purposes. It served to keep track of how many times observations were recorded for all the pupils in the room, etc.

(2) Problem

The problem appearing on the screen was written down in its entirety (or problem description, if this was not possible).

(3) Trial 1

The following information was recorded:

- the exact answer given by the pupil;
- computer prompts or hints;

- interactions with operator or another pupil and the content of the interactions;
- use of paper and pencil;
- if the answer was given by the computer after a mistake and if the pupil examined the correct answer (this option does not exist on all systems, see Chapter 2 - Feedback).

(4) Trial 2

- The same information as described for trial 1.

(5) Trial 3

- The same information as described for trial 1.

(6) Comments

- This column was used to expand on items noted in one of the other columns. Also, the observer could note something of interest about the pupil's behavior preceeding or following the formal observation.

4. PROCEDURE

1. SAMPLING

The elementary schools using computer assisted instructional systems included in our sampling frame met four criteria:

1) The computer system was acquired by the school before January 1983.
We wanted to avoid schools which were having "start-up" difficulties. These are interesting in their own right, but we decided to focus on 'steady state,' normal operation. It was therefore decided to observe in schools that obtained the computer system at least a year before observations were scheduled to start in February 1984.

2) The computers were used for the purpose of drill and practice in math.
We decided to focus on the use of math drill, whether the school used the computers solely for this purpose or not. The reason for this is that math programs are by far the most prevalent of the subject areas available and also the most developed.

3) The system was located in the school.
Schools using computer systems located in other schools were not included in the sampling frame since this mode of use will gradually disappear. Also the administrative difficulties associated with leaving the school grounds are likely to lead to a situation where the pupils are not working on the system as frequently as suggested by the distributors and where the communication between the operator of the computer room and the classroom teachers is likely to be less than called for by the distributor. We also excluded the few systems not located in schools (e.g., those in community centers).

4) The school was defined as disadvantaged or integrated.
Funding of the computer systems, up to 1984, was primarily by the Educational Welfare Program of the Ministry of Education and by Project Renewal, creating a situation in which the majority of computer systems were located in disadvantaged and integrated schools. This being the case, and since computers are seen by many as an efficient means for

improving the achievement of disadvantaged children, led us to focus on schools defined as disadvantaged or integrated.

The final sample of schools included three computer systems: **Mashov**, run on Atari computers; **Semel**, run on Commodore computers; **Toam 1** and **Toam 2** run on Dec mini-computers.

It was our intention to observe in schools using **Tapuach**, run on Apple computers, but at that time no schools were found that met all four criteria.

In addition, a number of other computer systems available on the market were not included in the sample. "Sesmal" was just beginning to distribute a computer system using Radio Shack computers, but only a few elementary schools were using this at the time sampling was carried out.

The number of schools using each system that met our criteria is presented in Table 1.

Table 1: The number of schools in the sampling frame.

System / Type	Toam 1	Toam 2	Mashov	Semel
Disadvantaged	15	5	8	3
Integrated	8	10	7	4

The **Toam** computer system consists of two systems. **Toam 1** is the older system and includes courseware for math drill and practice exclusively and today is being phased out. **Toam 2** is a newer system, run on a more powerful computer and includes the material from **Toam 1** as well as courseware in other subject areas. The distributor of **Toam** suggested that for sampling purposes **Toam 1** and **Toam 2** be related to as separate systems, which we did.

2. THE SAMPLE

In the main design we randomly selected 3 disadvantaged and 3 integrated schools from the **Mashov, Semel** and **Toam 2** schools. The one exception was **Semel** disadvantaged schools, 2 were selected, due to the few number of schools in this category.

Parallel to the main design, also included in the sample were three **Toam 1** disadvantaged schools. After the above random sampling we added, ad hoc, a **Semel** advantaged school as a reference point for this category. We chose a **Semel** school because a proportionately large number of advantaged schools were using **Semel**.

In Table 2 we present the number of schools in the main design (inside bold lines) and in the secondary design according to system and type of school.

Table 2: The main and secondary design.

System / Type	Toam 1	Toam 2	Mashov	Semel	Total
Disadvantaged	3	3	3	2	11
Integrated		3	3	3	9
Advantaged				1	1
Total	3	6	6	6	21

3. FIELD OBSERVATIONS

Contact with schools

After acquiring formal permission from the Ministry of Education to observe in the schools sampled, preliminary contact was made with the schools. We received, by telephone, permission to observe in the computer room and interview staff and the computer room schedule. We were given full cooperation by all the schools sampled.

The focus of the observations was on 4th and 6th grade math drill and practice lessons and visits were scheduled accordingly. However, all lessons that took place on the same day were observed. These included different grade levels, different subject areas and the observation of classes from other schools using the system. The data obtained provided a basis for examining the generality of our findings in grade 4 and 6 math lessons.

Training of observers

From September 83 to February 84, the observers were trained by staff members in two stages. The observers were introduced to the observational instruments and made initial observations using a video tape of children working with the computer systems. They were then field tested in schools in the Jerusalem area.

Observation procedure

Ideally, two observers were present during all observations. The observers waited 3 minutes from when the lesson officially began before beginning the observations in order to avoid observing the invariable first three minutes of disorder.

During the first lesson of the day, the observers did reliability testing using the **Activities** observation. Using the same timer and observing the same pupils, the two observers noted 100 behaviors. Percent agreement was calculated and if the percent agreement was above 80%, one observer continued with the **Activities** observation and the other began the **Process** observation. If the percent agreement was below 80% (this rarely occured) the observers analyzed the disagreement and again did a reliability test.

About midway through the lesson, the observers switched observation instruments and continued thus until the end of the lesson. In some cases a single observer was present. Generally, in this case each type of observation was carried out for half the period.

The observations were carried out between February and May 1984. In Table 3 it can be seen that 212 lessons were observed; 175 math and 37 language. In addition, seven lessons for children from other schools were observed (noted in parentheses in the table). In two Semel schools grade 4 children did not use the computer room.

Table 3: The number of lessons observed by grade level.

Grade / System	2 & 3	4	5	6	7 & 8	Total
Toam I Disadvantaged	5 (4)	10 (2)	4	9	--	28 (6)
Toam II Disadvantaged	14	9	3	11	--	37
Toam II Integrated	9	15	14	8	1	47
Mashov Disadvantaged	1	9	1	9	--	20
Mashov Integrated	--	12	1	12	1	26
Semel Disadvantaged	1	6	2	12 (1)	3	24 (1)
Semel Integrated	3	8	--	10	2	23
Semel Advantaged	--	1	--	3	3	7
Total	33 (4)	70 (2)	25	74 (1)	10	212 (7)

Analysis of observer interference

We took the category 'looking at the observer' from the **Activities** observation as an indication of observer interference. However, it should be noted that the meaning of this category of behavior is ambiguous, since,

in some of the cases it was clear that pupils were doing this while 'thinking out' a problem. In any case 'looking at observer' occurred only 2.3% of the time in grade 4 and 1.4% of the time in grade 6. Also, this behavior occurred more in disadvantaged schools than in integrated schools (3.2% versus 1.6% in grade 4 and 1.8% versus 1.1% in grade 6).

We also examined this variable as a function of visit (first versus second). We were concerned that during the first visit the children might be overly distracted by the observer. This would manifest itself in a fairly high percent of 'looking at observer' during the first visit compared to the second. The occurance of this behavior was summarized over lessons in which the first lesson and the second lesson observed for that class was in the same subject area. We subtracted the percent 'looking at observer' for the second lesson from percent 'looking at observer' for the first lesson. This was done for 47 pairs of lessons. The average difference was .1% (SD = 2.32). The difference is negligibly small and on the basis of this and the relatively low percent overall, we conclude that the **Activities** observation did not distract the children.

5. COMPUTER ROOM USE AND STAFFING

In this chapter we examine utilization patterns of the computer room and staffing. First, we present the utilization of the computer room in general. We look at scheduling, the number of hours per week the system was in use, the distribution of these hours according to the subject matter and grade levels, the extent of utilization by neighboring schools and utilization outside of school hours. Second, we examine the extent of the utilization of the terminals within the computer room. We present the number of stations utilized, malfunctions during the lessons, the number of stations not in use due to technical problems requiring professional servicing and students' complaints relating to technical problems. Third, we examine staff training and roles and fourth, we examine pupil-staff ratios.

1. UTILIZATION OF COMPUTER ROOM

Scheduling

In general, we found three models of scheduling which were determined by the number of stations in the school.

Model 1: (Two **Semel** schools and five **Toam 2** schools)

The school had a system with a large number of stations, between 25 and 40, which allowed an entire class to use the computers at the same time. In this model the teacher may or may not be with the class in the computer room. Schools using this model do not necessarily have to depend on extra staff.

One of the **Semel** schools had only 16 stations, but established ability groups in math and language, third and fourth grade combined, fifth and sixth grade combined. In this manner, ability groups were small enough to work in the computer room at the same time accompanied by their teacher.

Model 2: (Three **Semel** schools)
The school had only a few stations (5 to 7) and the computers occupied one part of a classroom. In this model, the whole class came to the room. The pupils not using the computers worked on activities provided by the teacher, and rotated as the pupils finished their session on the computer. Schools using this model do not necessarily have to depend on extra staff.

Model 3: (Six **Mashov**, one **Semel**, three **Toam 1** and one **Toam 2** schools)
The school had a system with 10 to 20 stations, which allowed half the class to work at the same time. The other half of the class was with the teacher in the classroom, or in a room next to the computer room set aside for this purpose, and rotated as the pupils finished their session on the computer. Schools using this model had to use extra staff, one staff member in the computer room and one with the rest of the class. In one of the **Semel** schools (with 16 stations), from 2nd through 5th grade, the teacher was in the computer room with half the class while a tutor, from one of the higher grades, was responsible for the other half in the playground.

Also, three disadvantaged schools (one from each system) had youth doing their national service help in the computer room (generally in the religious schools where girls serve in this manner instead of the army). Another school utilized student teachers who worked one day a week at the school.

Amount of use
In Table 1 it can be seen that there was tremendous variability between schools within each of the systems. For example, number of hours of use in **Semel** schools varied between 10 and 30 hours per week; in **Mashov** between 16 and 35 hours per week; and in **Toam** between 20 to 40 hours per week. However, on the average, schools using **Toam** and **Mashov** utilized the computer room about thirty hours per week, which in our view is about as efficient as one could expect (five hours of use per day).

Table 1: Hours per week the computer room is utilized.

System	TOAM I			TOAM II						MASHOV						SEMEL					
Type*	D			D			I			D			I			D		I			A
School	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Hours per week	20	40	37	32	30	28	33	30	35	35	23	16	32	35	34	21	27	10	29	28	30
Average	32			30			33			25			34			24		22			30

* D = disadvantaged I = integrated A = advantaged

The somewhat lower average for Semel was not statistically significant and was largely due to one school which greatly reduced system use because of budgetary problems. It will be interesting to see if cut backs in educational budgets will have similar effects in other schools.

Distribution of courseware use according to grade level

In Table 2, it can be seen that over all systems, most usage was in math drill and practice (about 60% for all systems except Toam 1, which was exclusively math) followed by language drill and practice (about 30%) and by English (about 10%).

Table 2: The use of the computer room by subject.

SUBJECT / SYSTEM	MATH	LANGUAGE	ENGLISH
TOAM 1	100 %	-	-
TOAM 2	66.7 %	27.3 %	6.0 %
MASHOV	55.8 %	36.8 %	7.4 %
SEMEL	56.3 %	29.1 %	14.6 %

Since the courseware existing for **Toam 1** is exclusively math drill, in all three schools the utilization of the system was more or less similar. The pupils started in 2nd grade and worked 40 minutes per week, except in one school where the pupils from third grade worked 60 minutes a week.

In **Mashov, Semel** and **Toam** schools, the utilization of the computer room at the different grade levels and in the different subject areas was related to size of the school, the number of stations in the school and variety of existing courseware. The differences among the schools and the systems were great and are briefly summarized by system below.

Toam 2: Math drill started in 2nd grade and children generally worked 40 minutes per week. From third grade on, the pupils generally worked an additional 20 minutes per week on reading comprehension. In 6th grade and up (depending on how many grades the school had) the pupils worked on English 20 to 40 minutes per week.

Mashov: Although the math drill is geared to the 4th and 6th grades three of the six schools used it for other grades as well. One school started in 3rd grade and two schools used it for weak students in the 5th, 7th and 8th grades. In most of the schools these classes worked 40 minutes per week in math. Although the language program is geared for the 5th and 6th grade, two schools started from 4th grade, 3 schools began in 5th grade and one school used the language drill in 6th grade only. The pupils worked on the language drill between 20 to 40 minutes a week. English was used in three schools, starting in 7th grade in one school and in the other two in the 8th grade.

Semel: In **Semel** schools the variation of use was the greatest. This was, in part, due to the fact that five out of the six schools continued through the 8th grades. The number of stations per school also varied greatly; three schools had up to 7 stations, two schools had 15 and one school had 40 stations. These two factors dictated the amount of time devoted to each

grade level and the use of the different courseware. In math, one school started in 2nd grade, two schools started in 3rd grade, one in the 4th grade and two schools started in the 5th grade. Interestingly, while **Semel** does not recommend usage below grade 5, four out of six **Semel** schools were doing this. In the three schools that had relatively few stations, the pupils worked 20 minutes per week and in the other schools, the pupils worked on math 40 minutes per week. The language program was used in all of the schools but each school used it in different grades and for different amounts of time per week. English was used in five of the schools in the 6th grade for 20 minutes per week and in one school in 6th through 8th grade, 40 minutes per week.

In summary, most classes spent 40 minutes per week in the computer room working on math, while most classes spent 20 minutes per week in the computer room working on language and English. Most utilization of the math and language drill was at grades 4, 5 and 6 while usage of the English drill was in grades 6, 7 and 8. In general, **Toam** had greater utilization over other grade levels than did **Semel** and **Mashov**. In all the systems, the 6th grade worked in the computer room more than any other grade level.

Utilization by neighboring schools and extracurricular activities

Toam had much greater utilization of the system by neighboring schools than did **Mashov** and **Semel** (8 out of 9 schools versus 1 out of 6 for **Mashov** and **Semel**). This can be seen as a result of size of the system and administrative policy. For example, local municipalities sometimes fund the aquisition of computers for all the schools in the area, in which case, the system is installed in the most centralized location and is intended for the use of all the schools. Because **Toam** is generally the largest system, it is reasonable that this happened most often in the **Toam** schools in our sample. In addition, the number of stations in **Toam** is standard in comparison to the other systems which can start with few stations and add on.

On the other hand, Mashov and Semel computer rooms were more likely to be used after school hours. In 6 out of 6 schools and 4 out of 6 schools respectively the computer room was used after school hours versus 0 out of 3 Toam 1 schools and 3 out of 6 Toam 2 schools. In Table 3 the types of activities held after the school hours are listed.

Table 3: Activities held after school in the computer room.

SYSTEM	ACTIVITIES AFTER SCHOOL HOURS
TOAM 1 3 out of 3 schools	NONE
TOAM 2 3 out of 6 schools	BASIC, ADULT EDUCATION, MAKE UP LESSONS
MASHOV 6 out of 6 schools	BASIC, ADULT EDUCATION, MAKE UP LESSONS, ENRICHMENT, GAMES
SEMEL 4 out of 6 schools	BASIC, ADULT EDUCATION, MAKE UP LESSONS, ENRICHMENT, GAMES, LOGO

Schools which served many neighborhoods reported that they would have liked to expand the utilization of the computer rooms after school hours but were limited because the children did not live within walking distance.

In general, we saw that computer rooms in schools were efficiently utilized in all systems.

2. UTILIZATION OF STATIONS

We turn now to utilization of computer stations. In our **Activities** observation we noted three reasons for stations being empty: malfunctions; non-utilization of stations because of a surplus for the particular class

using the room; changeover between children, or a child momentarily leaving the station. In Table 4 we present data describing the extent of malfunctioning and utilization of terminals.

Table 4: Utilization of terminals.

System* / Utilization	Toam 1 D	Toam 2 D	Toam 2 I	Mashov D	Mashov I	Semel D	Semel I
Average over lessons: Percent of lessons with at least one malfunction.	0	0	5.3	26.3	46.2	19.0	28.6
Average over lessons: Percent of terminals with at least one malfunction during a lesson.	0	0	0.3	5.0	7.8	7.8	3.4
Average over lessons: Percent of terminals with a malfunction lasting the entire day of observation.	0	0	0	1.5	0	0	0
Average over lessons: Percent of time stations were malfunctioning.	0	0	~0	1.4	4.8	2.4	0.7
Average over schools: Percent of students complaining about malfunctions.	0	0	1.5	2.6	4.2	10.0	25.0
Percent of time stations were utilized. AV	77.6	83.2	75.5	84.4	81.8	81.6	88.1
SD	14.3	17.4	13.8	11.8	12.0	12.0	10.0

* D = disadvantaged schools I = integrated schools

Table 4 does not include information for the Semel advantaged school. This was due to the unusually large number of terminals (40) which are located in one large room with a moveable partition. Sometimes two classes were in

the room at the same time, in which case, we did not observe all the stations during the lesson, and focused on 4th or 6th grade students. Therefore the data on utilization for this school is not complete.

It can be seen that there was virtually no malfunctioning in **Toam** 1 or in **Toam** 2. In about one third of the lessons in the **Mashov** schools and one fourth in **Semel** there was at least one malfunction which translated into three to eight percent of the terminals. Virtually all these malfunctions were minor and were corrected during the same lesson or later in the day. In only one **Mashov** school did a malfunction last the entire day of observations. Also, the percent of time stations were malfunctioning was quite small (1.4% to 4.8%). The relatively high average for **Mashov**, integrated schools (4.8%) was due to one school with extraordinarily many problems.

The relatively low malfunction rates are encouraging. However, one should consider that malfunctions are frustrating. For example a momentary malfunction while a child is in the process of solving a relatively complex problem will in all likelihood have a large, frustrating effect, even when it is immediately corrected. This is indicated in the results of a questionaire completed by sixth grade children in all the schools in the sample. In an open format they were asked to list things they most liked and things they most disliked about their work with computers. In Table 4, it can be seen that virtually no children working with **Toam** complained about malfunctions, while close to 4% of the children working on **Mashov** complained, versus about 18% of the children working on **Semel**. It was not expected on the basis of the data on malfunctioning that **Semel** children would be affected so differently from **Mashov** children. We thought it might be due to fewer terminals in most **Semel** schools, a factor that would reduce the possibility that a child could work on another terminal. However, the percent of complaints was about the same in **Semel** schools with many terminals and with few terminals. We feel that the finding is due to the mathematics game that **Semel** provides automatically in the middle of the

lesson. In our computer room we observed that children look forward to the game, and if a malfunction occurs before they receive the game the children become upset. In comparison, in the other systems, where the content is fairly monotone during the lesson, the children are not looking forward to a peak experience, such as a game, during the lesson. The importance given to the game by pupils working on **Semel** is stated quite clearly in the questionaires. When asked "What I like about the computer" approximately 80% of the pupils cited the game. Also, the overall comments of **Semel** children were more positive than those of **Toam** and **Mashov** children (see Chapter 9, Pupil's Attitudes).

We conclude that **Semel** children may be frustrated by malfunctions; Mashov children to a slight extent; and **Toam** children not at all.

In the last line of Table 4 we present the percent of time terminals were utilized. The deviation from 100% is a result of either malfunctions or non-utilization.

Malfunctioning rarely occurred so that percent utilization is largely a reflection of school administrative patterns and the number of terminals in the room and class size. In the Semel schools with few terminals the percent utilization was close to 100%. However, when the number of terminals was above ten there was no clear relationship between number of terminals and percent utilization. Therefore, it seems that administrative patterns largely affected the extent of utilization. We saw this in one **Toam** school where the operator went to great lengths to insure that all terminals were in use all of the time. The operator noted the number of empty stations at the beginning of each lesson and went to bring children who were weak in math or who had missed previous lessons.

In general, utilization of terminals was reasonable in all systems and types of schools. It is encouraging that utilization was not lower in disadvantaged schools, than in integrated schools.

3. SCHOOL STAFF IN THE COMPUTER ROOM

The utilization of a computer system in the school is, in part, dependent on what is required of the staff administratively and technically. It is also dependent on how extensively the work with the computers is integrated with classroom teaching. This can be seen as a function of the school policy, the computer system constraints, the training and on-going guidance of staff.

Most of the information pertaining to training and guidance given by distributors is based on Davis et al (1981) in a survey of five computer systems (an earlier stage to the present research). Also, information was obtained by members of our research staff who participated in the in-service training of Mashov and Semel.

The information pertaining to staff in the computer room is based on our observations as well as interviews of the principal and computer coordinator in each school.

Since we did not observe in Tapuach schools, all information for this system is based on the distributor's report and is not documentated by field follow-up. Also, two Toam schools in the sample shared a computer room and coordinator and therefore when summarizing the interviews of the coordinators, we include 8 coordinators for the 9 Toam schools in the sample.

Training and guidance as reported by the distributors

In this section, 'coordinator' refers to the staff member responsible for technical duties, such as printing and distributing progress reports, and coordinating computer room activities.

We use the term 'operator' to indicate the staff member present in the computer room while the pupils are working, whose responsibilities include helping pupils when necessary, maintaining discipline, and dealing with

technical problems. The 'operator' may be the coordinator, the class teacher, or may be a staff member whose responsiblity is running the computer room.

All the distributors suggested that the coordinator be a school staff member who is trained before the school begins to use the computers. The specified pre-service training was more or less the same for all the systems. It included system operation, common technical problems, dealing with malfunctions, the courseware, guidelines for integration of the drill and practice into the classroom teaching and use of the progress reports supplied by the computers.

It was suggested by all the distributors that the coordinator participate in on going guidance which, in general, consisted of one to three day workshops two to three times a year, in which new courseware or changes in the existing courseware were presented.

In addition to the pre-service training and workshops, two of the systems, **Semel** and **Toam**, provided counselors who were responsible for the needs of the school staff. **Toam** suggested regular meetings between the counselor and school staff, approximately once a month, in order to answer questions raised by the teachers and to update materials. The counselor from **Semel** was to be in close contact with the coordinator during the run-in period, and on-going guidance was only given if requested. **Mashov** and **Tapuach** did not provide for counselors but guidance was provided if requested.

Three distributors, **Mashov**, **Semel** and **Tapuach** developed authoring languages, and frameworks existed in which staff members were actively writing courseware. All held workshops during the year centered on their authoring languages.

Training and guidance as reported by the coordinators and/or operators

Mashov: In all 6 schools the guidance and training was as reported by the distributor. In all schools the staff also participated, the extent differing from school to school.

Semel: The coordinator and staff of 4 out of the 5 schools providing data were actively involved in on-going guidance. In one of these schools, it was reported that during the run-in period a workshop was held for the entire staff once a week. In 1 out of the 5 schools it was reported that only the coordinator was actively involved in the guidance given.

Toam: The majority of the coordinators (5 out of 8) reported that guidance was given as stated by the distributor. In 7 of the schools it was reported that the coordinator and staff participated in guidance and in the other 2 schools only the coordinator participated.

In one **Mashov** and in two **Semel** schools we visited some teachers participated in one of the established writing teams. **Toam** did not use an authoring language but teachers were invited to cooperate with the **Toam** staff in developing courseware. Out of the 9 **Toam** schools visited, no teacher was involved in the development of courseware.

In addition to the training given by the distributors, the coordinators were asked if they had received training from other sources. Approximately half the coordinators had participated or were participating in courses given at Universities, the Technion, Teachers Seminars and at the Institute for Teaching Aids (4 from **Toam** schools, 2 from **Mashov** schools and 2 from **Semel** schools). Various subjects were studied including computer literacy, programing and computers in education. The participation of the coordinators in these courses reflects the desire to incorporate computers into their schools in areas other than drill and practice.

The role of the operator

Semel: Semel suggested that teachers be present with their class when it was in the computer room. In Semel's opinion, the teacher should be capable of running the computers and dealing with the minor technical problems. This is a reflection of Semel's policy of direct involvement of the teachers. As for teacher support during the lesson, Semel suggested that the teacher use his/her judgement concerning intervention while the children are working.

Toam: Toam stressed that operator interaction should be minimal. In Toam's opinion, intervention should be given by the teacher and that problems should be attended to on the basis of the progress report supplied by the system. The student should develop skills necessary to work independently and intervention during the computer lesson was not seen as productive. To enable intervention, a device had to be used by the operator to stop the clock. This made intervention difficult for the operator who had to arrive at the pupil's station in time to stop the clock before the problem changed. Nine percent of Toam pupils noted on an attitude questionaire that they were bothered by the fact that the time element prevented them from asking questions. This is an indication that Toam pupils, on the whole, were not bothered by this policy.

Mashov and Tapuach had no set guidelines concerning the role of the operator.

In our observations we also noted to what extent the class teacher was present in the computer room (as operator or in addition to the operator) while the class was working. The percent of the lessons observed in which the teacher was present is presented in Table 5 below. 'Operator only' indicates that the class teacher was not present in the computer room.

Table 5: The percent of lessons where the teacher was present.

STAFF / SYSTEM	TEACHER	OPERATOR ONLY
MASHOV 47 LESSONS	23	77
SEMEL 55 LESSONS	89	11
TOAM 112 LESSONS	69	31

It can be seen from the table that the teacher was present in the computer room most frequently in the **Semel** schools (89% of the lessons observed), which is in accordance to the suggested guidelines of **Semel**, followed by **Toam** schools (69%). In the **Mashov** schools the teacher was least likely to be present (23%). In most of the **Mashov** lessons half the class was in the computer room with an operator while the other half of the class was in an adjacent learning room with the teacher.

The use of progress reports

The coordinators were asked if and how often they printed out a progress report. Their answers are presented in Table 6.

Table 6: Frequency of printing progress reports.

FREQUENCY / SYSTEM	EVERY LESSON	ONCE A WEEK	EVERY 2 WEEKS	EVERY 3 - 4 WEEKS
MASHOV 6 SCHOOLS	-	4	1	1
SEMEL 5 SCHOOLS	-	-	1	4
TOAM 8 SCHOOLS	1	5	2	-

It can be seen from the table that the frequency of printing the progress reports was similar for Mashov and Toam schools, in most cases once a week. In Semel schools, progress reports were printed least often. In the interviews, the Semel coordinators reported that the progress reports were not printed often because the teacher was present in the room while the children were working and therefore had on-going feedback concerning their progress and problems.

One of the questions asked the coordinator during the interview concerned the way progress reports were given to teachers and utilized. The fact that the teachers themselves were not interviewed nor observed in the classrooms limits the usefullness of the information obtained. However, it is worth noting the way in which the reports were given to teachers. We distinguished two ways: The coordinator read and analyzed the progress reports with the teacher; The coordinator distributed the reports to the teachers for their own use. The first way, we feel, is indicative of a more serious attitude toward the reports. However, it does not guarantee that the teacher actually uses the information.

We found that in four out of five Semel schools the coordinator and the teacher read and analyzed the progress reports together; in four out of eight Toam schools the coordinator and the teacher read the reports together; in two out of six Mashov schools the coordinator and the teacher read the report together. We see that the differences reflect the policies and operating procedures of each system. However, the general impression received from the observations and spontaneous talks with school staff was that the cooperation between coordinator and staff was, to a great extent, dependent on the staff relationships as a whole. For example, one operator was one of the most experienced staff members and highly respected. The cooperation between the coordinator and staff was extensive, including the planning of strategies of how to approach and work on specific problems which were seen in the progress reports. In another school, the coordinator was not accepted by the staff and his responsibilities were

reduced to the technical running of the computer room, leaving him frustrated and uninvolved. Cooperation, involvement and responsibilities are therefore seen to be more a function of the relationships among staff members than of the system.

4. PUPIL - STAFF RATIOS IN THE COMPUTER ROOM

All systems reported that only one staff member was needed in the computer room with the pupils. During the observation sessions the number of staff members in the room was noted. If one of them was only there for part of a lesson, this was recorded as 0.5 staff members rather than one (this only occurred in 19 lessons out of the 196 in which this data was recorded).

We found tremendous variation among schools within the same system and much overlap among systems. As a result we present data separately for schools within systems. In Table 7 we present percent of lessons in which more than one staff member was present. The variation among schools within a system is highlighted in Team 2, schools 4 and 5: In all 13 lessons of school 5 more than one staff member was present while in all 7 lessons of school 4 only one staff member was present. Large differences were also found among Semel and Mashov schools. We conclude, then, that allocation of staff is largely a function of school policy and not system constraints or requirements.

In the second part of Table 7 we present average pupil-staff ratio.* This also varied widely within systems and was in general very low (median=12, range - 8 to 33). These results indicate that at this stage computers cannot be seen as saving manpower. We relate to this further in the summary and discussion.

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* In Semel schools where part of the class was working with the teacher and part was working with computers in the same room, the number of pupils was the entire class.

Table 7: Pupil-staff ratios in the computer room.

System Type*	Toam I D			Toam II D			Toam II I			Mashov D			Mashov I			Semel D		Semel I			Semel A
School	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Number of observations	7	5	13	7	13	15	14	9	15	6	8	6	9	11	6	10	12	4	13	6	7
Percent of lessons with more than one adult	29	80	31	0	100	73	14	56	20	50	25	0	22	0	0	10	33	100	54	0	71
Cell average	40 SD=19.9 N=25			68 SD=36.6 N=35			26 SD=16.7 N=38			25 SD=19.4 N=20			8 SD=10.5 N=26			23 SD=11.5 N=22		48 SD=33.0 N=23			71 SD=0 N=7
Pupil-staff ratio in the computer room	10.8	8.7	11.7	27.9	9.4	14.1	20.2	12.3	15.2	10.0	10.8	9.7	8.3	13.8	10.8	14.9	9.3	11.5	11.0	32.8	21.3
Cell average	10.9 SD=1.1 N=25			15.1 SD=6.7 N=35			16.3 SD=3.1 N=38			10.2 SD=0.5 N=20			11.2 SD=2.4 N=26			11.8 SD=2.8 N=22		16.8 SD=9.5 N=23			21.3 SD=0 N=7

* D = disadvantaged schools I = integrated schools A = advantaged school

6. ACTIVITIES IN THE COMPUTER ROOM

In this chapter we describe activity patterns in 105 4th and 6th grade math lessons. We excluded 7 lessons of children from other schools and 8 lessons in which fewer than 50 behaviors were recorded.

The 100% for activities does not include the categories - malfunction or empty station. It, also, does not include the category 'activity not clear.' This occurred in relatively few lessons and was generally less than one percent of the observations. In all, 32,196 activities were observed in the 192 lessons providing activity data. The average per lesson was 168. In the math 4th and 6th grade analyses 19,715 activities were observed in 105 lessons. The sample sizes for lessons are shown in Table 1.

Table 1: Number of math lessons as a function of system and type of school.

Grade 4

System \ Type*	D	I	A	TOT
Toam I	7			7
Toam II	6	8		14
Mashov	6	12		18
Semel	4	5	1	10
Total	23	25	1	49

Grade 6

System \ Type*	D	I	A	TOT
Toam I	8			8
Toam II	5	7		12
Mashov	8	8		16
Semel	7	10	3	20
Total	28	25	3	56

* D = disadvantaged schools I = integrated schools A = advantaged school

The unit of analysis is the lesson and the data are percent observations of each of the 19 activities for the lesson. For each cell of the design (which is a system, type of school combination) the percents were averaged over lessons. The design is basically hierarchical: lessons are nested in schools which, in turn, are nested in cells. An alternative way of summerizing the data would be to view the school as the unit of analysis and to aggregate the results for schools which are then averaged. We analyzed the data in both ways and found only minor differences. Simply

averaging over lessons is much easier to deal with (verbally as well as statistically) so we present averages over lessons. However, the analyses of variance take the hierarchical nature of the data into account. As a result, the system and school-type effects were tested against the nested school effect, which, in turn, was tested against the nested lesson effect. Both lessons and schools can be viewed as random factors. Therefore, testing the system and school-type effects against the nested lesson effect would have resulted in upward bias in the F-tests (Dayton, 1970). Also, the hypothesis tests assume generalization to an infinite, theoretical population of lessons.*

We are sceptical of the utility of classical hypothesis testing (see Sawyer and Peter, 1984; Guttman, 1981 and Carver, 1978) and focus instead on descriptive measures. At best, we view the analysis of variance as "a useful 'act of discipline' (Cronbach and Snow, 1977) to sort out findings that may be worthy of more attenttion." (Sawyer and Peter, p. 570). Where relevant in the text, the results of the hypothesis tests are indicated. Summary tables and more detailed descriptive data can be obtained from the first author.

Reliability

In general, during the first lesson of the observation day each of the two observers recorded 100 behaviors using one timing device while observing the same children. The percent agreement was then calculated. If the percent agreement was over 80%, the two observers continued the observations, one with the activity instrument and one with the process instrument, switching instruments during the lesson as an additional control. If the percent agreement was less than 80%, the observers analyzed the source of disagreement and again began reliability testing

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* This decision and others were taken in consultation with the statistical counseling service of Hebrew University. However, we are responsible for final decisions. We wish to thank the service for its help.

until 80% agreement was met. This only occured twice. In all, 42 reliability checks were carried out. The average reliability was 95% and 37 of the 42 reliabilities were 90% or above (the other five were 80%, 86%, 87%, 87% and 89%). We view this observer agreement as satisfactory.

1. ENGAGEMENT WITH OTHERS*

In Figures 1 and 2, we present the percent of time pupils were:

1) directly interacting with the computer;
2) working with auxiliary materials (e.g., paper and pencil computations);
3) interacting with the teacher, or with another pupil;
4) not engaged in one of the above activities (this includes many possible behaviors, the majority being: waiting for the computer to present the next activity, waiting for the operator/teacher in order to ask a question, staring into space or at the observer).

Each bar graph summarizes the results over lessons for a particular system-level combination.** The number of schools at each level in the **Semel** sample varies and the width of the bar graph indicates when the data is summarized over one, two or three schools.

Direct interaction with the computer***

It can be seen that a much higher proportion of the time was spent in direct interaction with the computer in **Toam** in comparison to **Mashov** and

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* In the presentation and discussion of the results, we refer to the staff member present in the computer room as the 'teacher' for the sake of brevity although this is not strictly so. The staff member present in the computer room varies from school to school and from system to system. In Chapter 5 we discuss staff present in the computer room and the role of the operator.

** The sample size indicates the number of lessons summarized at each system-level combination.

*** The category 'game' (applicable only to **Semel** - see Chapter 3) was included in the category 'direct interaction with the computer'.

Semel. In grade 4, **Toam** pupils were engaged in direct interaction with the computer about 82% of the time versus about 50% of the time in **Mashov** and 60% for **Semel**. Similar differences were found in grade 6: about 86% for **Toam**; 55% for **Mashov** and 60% for **Semel**.

Use of auxiliary materials

In **Toam**, virtually no time was spent using auxiliary materials as opposed to 14 to 17 percent of the time for **Mashov** and **Semel**. This result for **Toam** was to be expected since **Toam** formally rejects the use of paper and pencil when working with their program in math. It is interesting to note that in five of the nine **Toam** schools a few children were observed using paper and pencil hidden under their terminal, writing on their hands or using spit to write with on the table top. However, **Toam**'s policy of working without pencil and paper was essentially implemented by all the schools.

Interaction with teacher or other pupils

The time spent in interactions with the teacher or other children varied from five to twelve percent in all systems. It was only slightly smaller in **Toam**, contrary to our expectation on the basis of differences in policy (**Toam** does not encourage interactions during the drill - see Chapter 2).

Not engaged

The last category includes activities in which the pupil was disengaged from the work on the computer, others in the computer room and auxiliary materials. This category includes most of the "unproductive" or not-on-task activities which will be examined in the next section.

In summary, there were strong differences among systems in terms of engagement of the child with others. **Toam** children were almost always engaged with the computer while **Mashov** children spent only about 50% of their time in direct interaction with the computer. There were no strong or consistent differences according to school-type. In general, sixth graders spent somewhat more time engaged with the computer and less time disengaged in comparison to fourth graders.

Figure 1: Average over lessons of percent engagement with the computer, auxiliary materials, teachers or other pupils (grade 4).

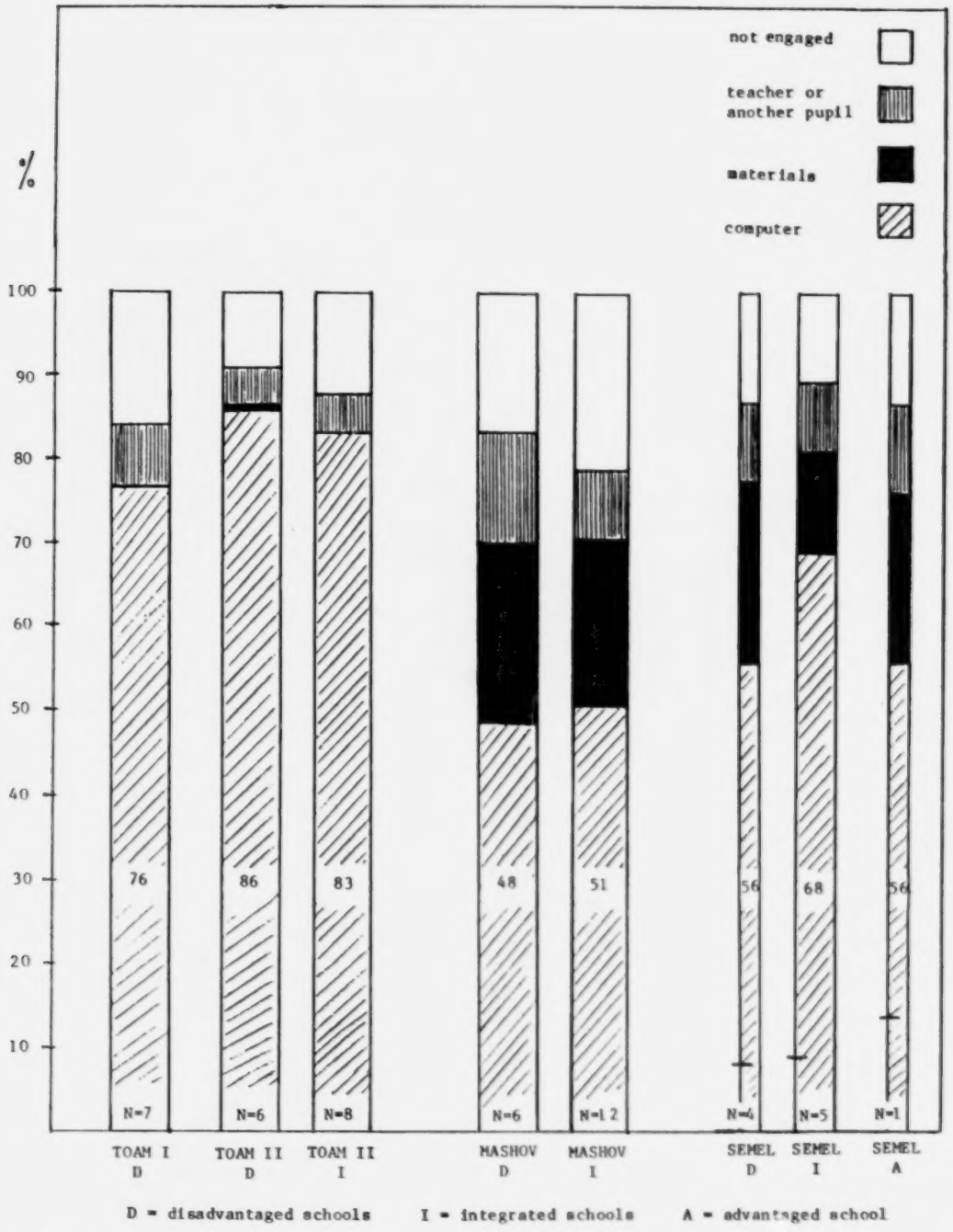
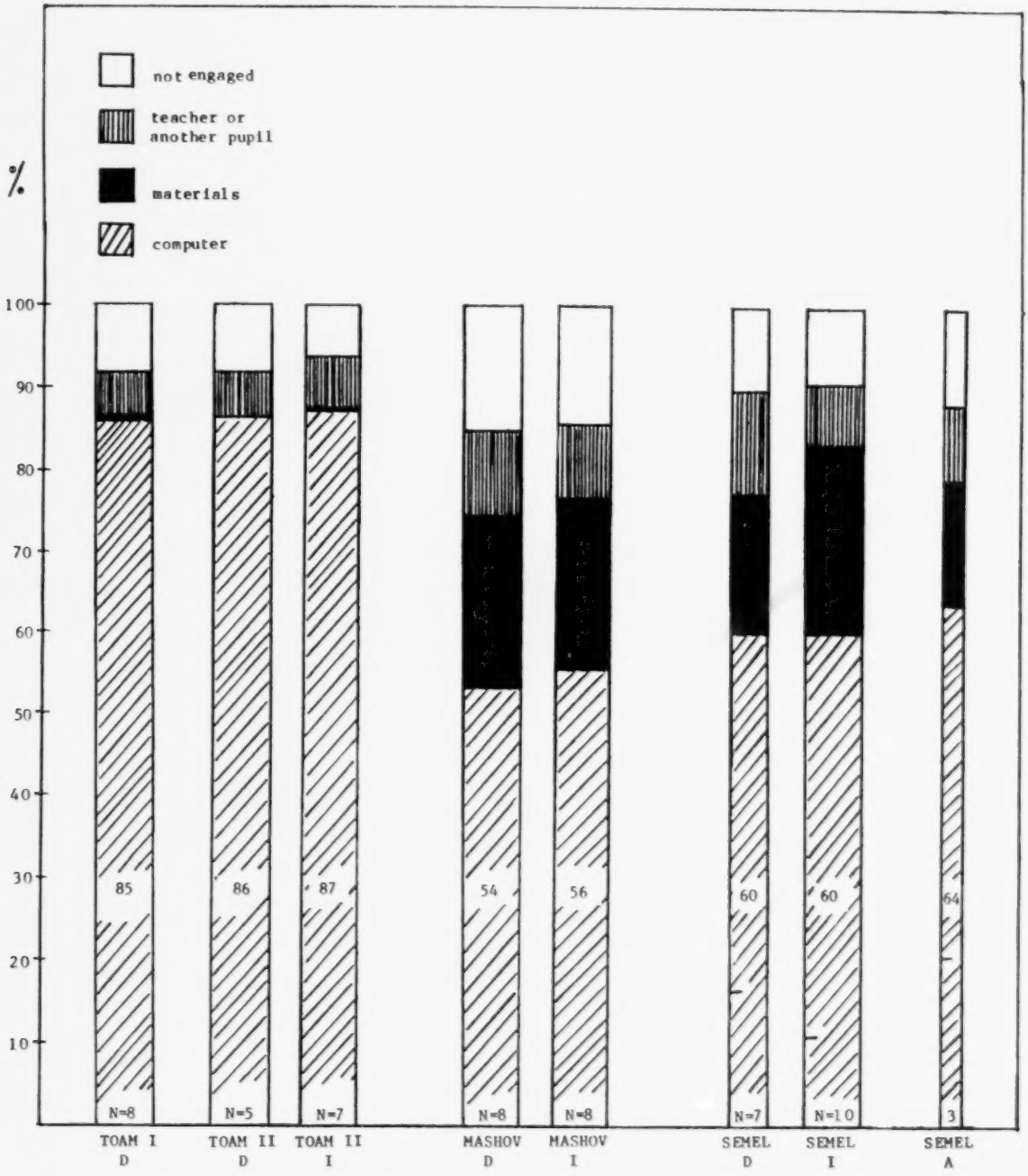


Figure 2: Average over lessons of percent engagement with the computer, auxiliary materials, teachers or other pupils (grade 6).



D = disadvantaged schools I = integrated schools A = advantaged school

2. TIME ON TASK

In Figures 3 and 4, we divided the children's activities into three groups: 1) definitely on task; 2) possibly on task; and 3) definitely not on task.

Activities defined as definitely on task:

- actively engaged with the computer
- using auxiliary materials
- interactions with teacher or another pupil which were task orientated

In this category we also included the three emotive responses which most likely were accompanying on-task behavior but which in any case, together, rarely exceeded one percent of the behaviors.

Activities defined as possibly on task:

- looking around or staring into space
- looking at the observer

In these cases the child might have been pondering the question or might have been distracted or day-dreaming. It was difficult to tell.

Activities defined as definitely not on task:

- teacher-pupil interaction concerning disruptive behavior
- pupil-pupil interaction which is disruptive
- disruptive behavior (e.g. shouting, throwing things, etc.)
- waiting for teacher help with hand raised
- entire class being scolded by the teacher
- waiting for the next activity from the computer

It can be seen that the percent of time definitely not on task was quite low in all systems and was lowest in Toam. For percent of time definitely on-task, the results are impressive for all systems. In 4th and 6th grade, the percent of time definitely on-task ranged from 81% to 92% in the Toam schools, from 77% to 84% in the Mashov schools, and from 81% to 89% in the Semel schools.

Figure 3: Average over lessons of percent time definitely on task, possibly on task and definitely not on task (grade 4).

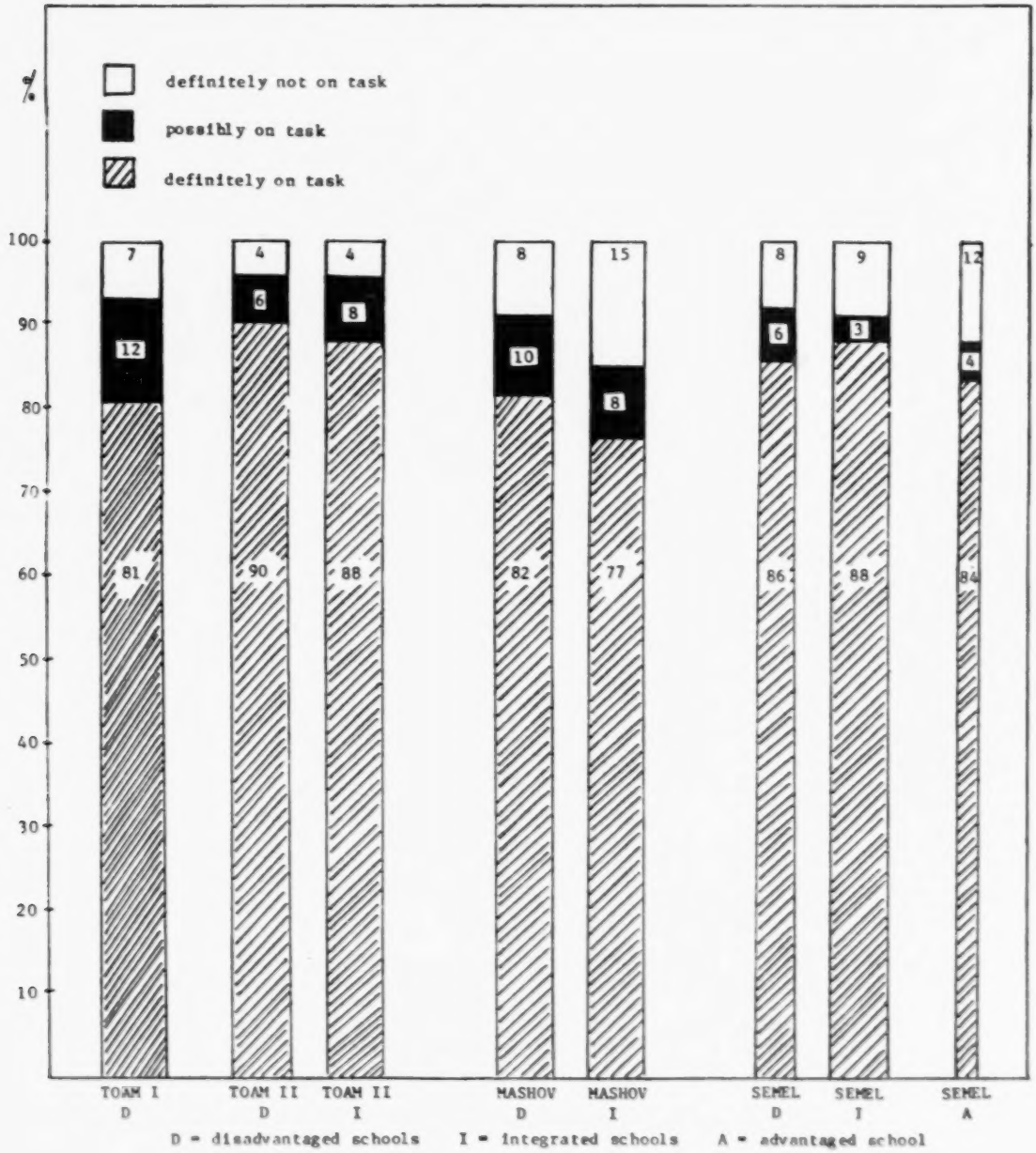
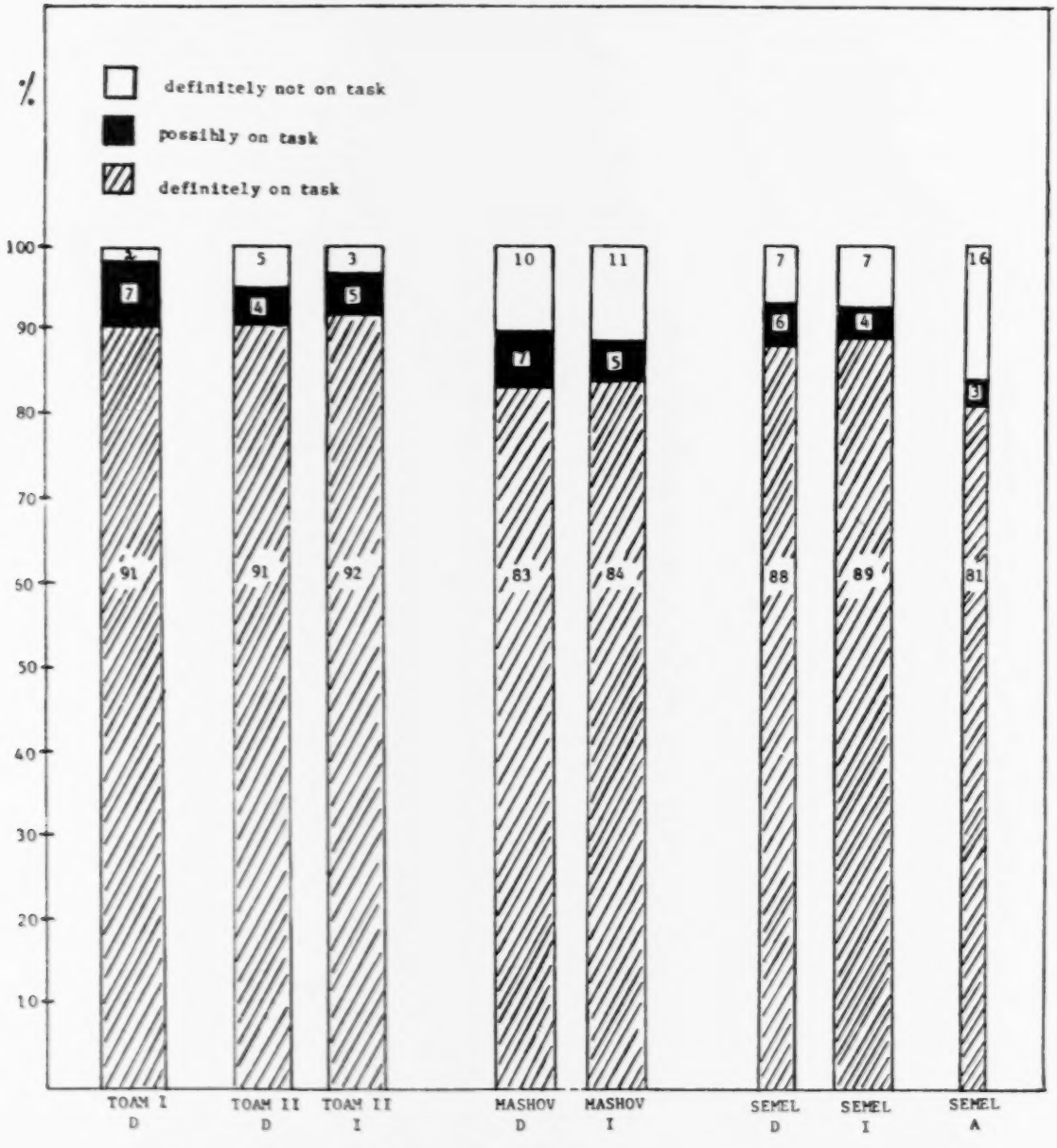


Figure 4: Average over lessons of percent time definitely on task, possibly on task and definitely not on task (grade 6).



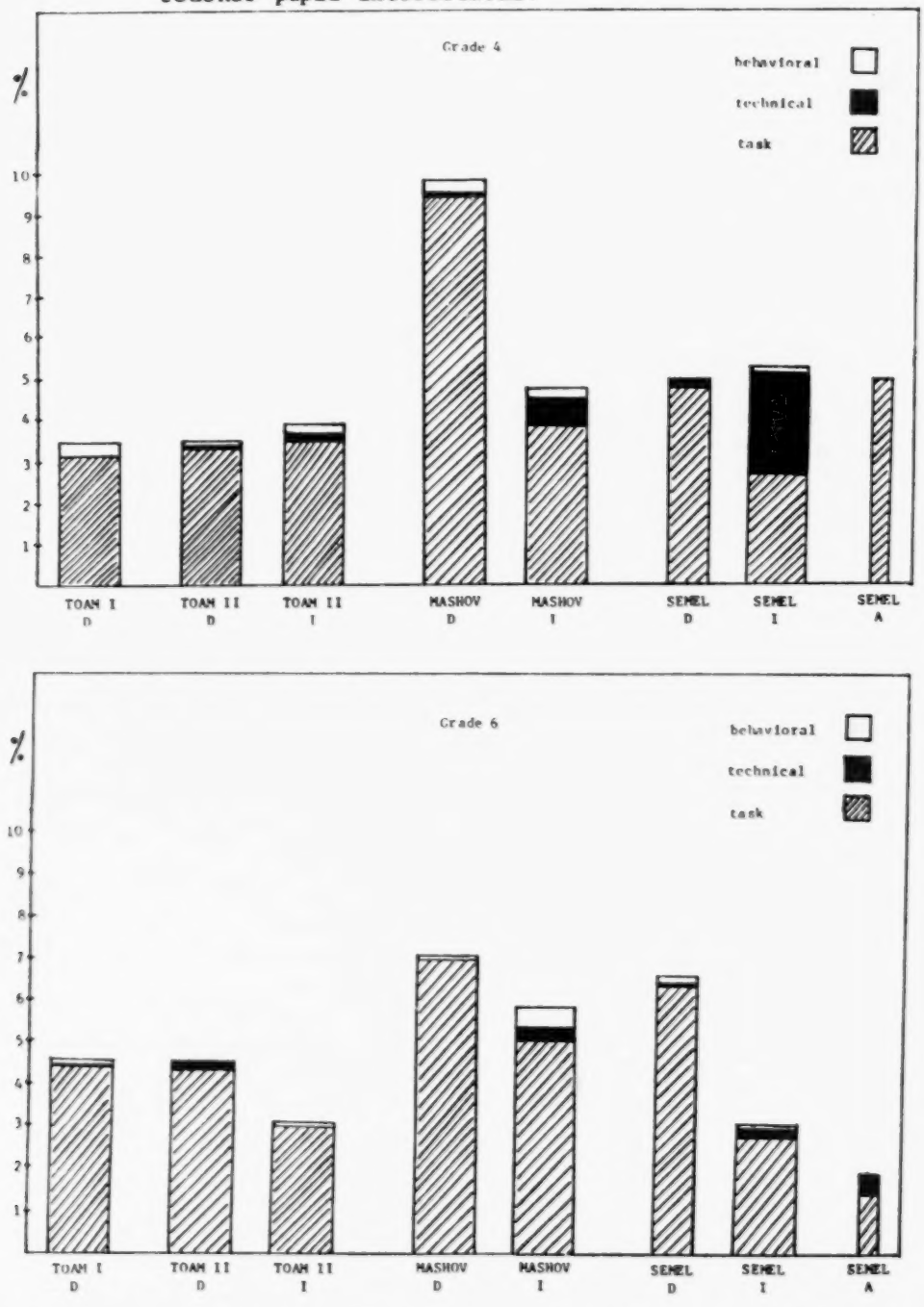
If we look at the percentages by type of school, it can be seen that there were no strong or consistent differences among disadvantaged, integrated and advantaged schools. This is an encouraging result since it was expected that children in disadvantaged schools would be less focused. The computer appears to have equalized time on task for disadvantaged and advantaged children. As expected from the previous section, sixth graders, in general, spent somewhat more time on definite task activities and somewhat less on non-task activities.

3. TEACHER-PUPIL INTERACTIONS

In Figure 5 we present a breakdown of teacher-pupil interactions. It can be seen that teacher-pupil interactions concerning technical matters and disruptive behavior occurred rarely in all systems. (The one exception was in **Semel** integrated schools, grade 4, but no differences were significant.)

In general there were fewer task oriented interactions in integrated compared to disadvantaged schools. (The only exception occurred in **Toam** 2, grade 4). This may reflect the greater need in these disadvantaged schools. It should be noted that the percentages and differences among them were small in absolute terms. However, the school-type differences were statistically significant ($p<.05$) and, more important, the difference between 4% and 6% teacher-pupil task oriented interactions in computer rooms could be educationally important. In general, **Mashov** had more teacher-pupil task-oriented interactions than the other systems. This may be a result of the complexity of presentation compared to the other systems (use of explanations and hints) and somewhat greater emphasis on problems involving mathematical concepts.

Figure 5: Average over lessons of task, technical and behavioral teacher-pupil interactions.

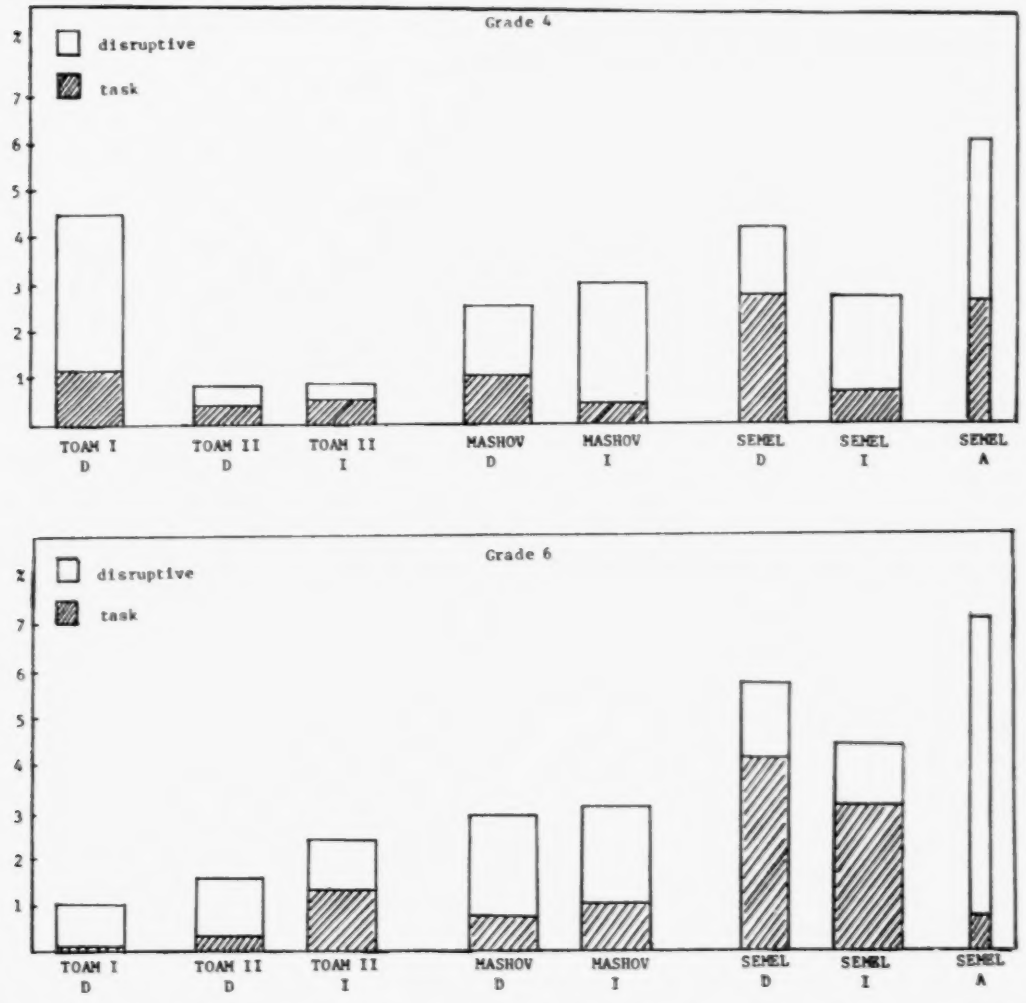


D = disadvantaged schools I = integrated schools A = advantaged school

4. PUPIL-PUPIL INTERACTIONS

In Figure 6 we present the breakdown of pupil-pupil interactions. In general, there were more task-orientated pupil interactions in **Semel** schools. There were no strong or consistent differences among school types.

Figure 6: Average over lessons of percent task and disruptive pupil-pupil interactions.



D = disadvantaged schools I = integrated schools A = advantaged school

5. WAITING TIME

One of the categories of not-on-task is 'waiting for program to continue'. **Toam** children virtually never waited (less than 0.5% of the time) compared to 3% to 5% waiting time for **Mashov** and **Semel**. The goal of **Toam** for attaining maximun efficiency in terms of number of problems per minute is clearly reflected here. It is hard to judge whether or not the 3% to 5% waiting time in **Mashov** and **Semel** is 'good' or 'bad'. We did not see any serious differences among the systems in signs of frustration or nervousness (which were negligibly small). Also, there were no complaints of children about waiting too long for computer changes. On the other hand, about 9% of **Toam** children complained about the time limit on problems.

7. PUPIL-COMPUTER INTERACTIONS

In this section we examine the process of child-computer interactions. At each station the observer waited until the child was presented with a new problem. He/she then recorded the content of the question, the child's response, the computer response, etc., until the problem was completed. The observer then moved away from the child, checked the recording, added comments when relevant and moved on to the next station. It was difficult in some cases to record the exact details in their entirety before the pupil responded and the problem changed (especially in word problems). However, the type of problem was almost always clear (e.g. multiplication of two numbers of the type: 28 x 53) and this was recorded. Out of all the problems observed, 0.3% were not identified by the observer.

The observer was instructed to be as unobtrusive as possible, and if the pupil showed signs of nervousness due to being observed, the observer withdrew and turned to the next child. This rarely occurred.

The information for each problem was later coded according to three categories; a) pupil response by trials, b) auxiliary help and c) problem type.

a) Pupil response: For each of the three possible trials (the number of trials given differed from system to system and also depended on the specific problem) one of nine categories were coded.
   1. Correct response.
   2. Incorrect response.
   3. Incorrect response - not specified.
      The exact response was not specified by observer.
   4. Incorrect response - repeated.
      The pupil entered the **same** answer previously judged wrong. This is applicable to the 2nd or 3rd trial.

5. Blind response.
   Random pressing of the keys.
6. Time lapse before response is entered.
   This is only applicable to **Toam** where pupils work against a clock.
7. End of observation before the problem was completed.
   The observation was ended by the observer due to lack of response over an extended period.
8. End of observation before the problem was completed.
   The pupil was stopped in the middle of the problem by the teacher.
9. Response not judged by computer.
   Applicable only in **Mashov** where the session always ends immediately after the pupil's first response after 20 minutes. The child receives no feedback regarding the correctness of the response. Instead, the message: "Your time is over" appears.

b) Auxiliary help: Five different types of auxiliary help were identified for each problem (coded as occurring or not occurring) as follows:

1. The pupil used pencil and paper.
2. The pupil received help from the operator/teacher.
3. The pupil received help from another student.
4. The pupil received a prompt (hint) from the computer.
   For this category we identified prompts as consisting of additional written information (help) which appeared automatically after a mistake had been made. For example, 'This problem requires multiplication.' This is distinguished from the prompting given in **Toam** where the exact position of the mistake is identified for the pupil whenever a mistake is made. The percent of this type of prompting was calculated directly from the observation sheets and is included in the analysis.
5. Other.
   The pupil used a hand calculator, multiplication chart, etc. This included the option in **Semel** where a calculator is provided for the pupils on the screen (this option exists for word problems only).

c) Problem type: Initially each problem was coded into one of 79 categories. At a later stage the categories were combined into 8 broad categories:

1. Whole number problems with numbers up to 100, drilling the 4 operations.
2. Whole number problems with numbers greater than 100, drilling the 4 operations.
3. Problems involving mathematical concepts (sum, product, greater than, less than, place value, etc.)
4. Word problems.
5. Problems with simple fractions, drilling the 4 operations.
6. Problems with decimal numbers, drilling the 4 operations.
7. Problems with negative numbers, drilling the 4 operations.
8. Problems with exponentials, drilling the 4 operations.

In addition to the 21 schools sampled, we also carried out this type of observation in our computer room in a Jerusalem school which included **Mashov**, **Semel** and **Tapuach** terminals. The school was officially classified as advantaged,* and we therefore added a **Mashov**-advantaged and a **Tapuach**-advantaged category to our presentation of results. The data from **Semel** was combined with that of the **Semel**-advantaged school in the sample of the 21 schools. In Table 1 we present the number of problems observed in each of the systems. It can be seen that there were many more problems observed for **Toam**. This is due to the time limit placed on answering and the fast pace of computer response.

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* There are many problems with the Ministry index for defining schools as disadvantaged. In fact, in this school many of the pupils came from one of the most disadvantaged neighborhoods in Jerusalem, and we have observed many children with learning difficulties in math.

Table 1: Number of problems observed according to system.

System	Toam 1	Toam 2		Mashov			Semel			Tapuach	
Type*	D	D	I	D	I	A	D	I	A	A	Total
Number of problems observed	573	427	496	116	155	391	187	284	423	312	3,364

* D = disadvantaged schools I = integrated schools A = advantaged schools

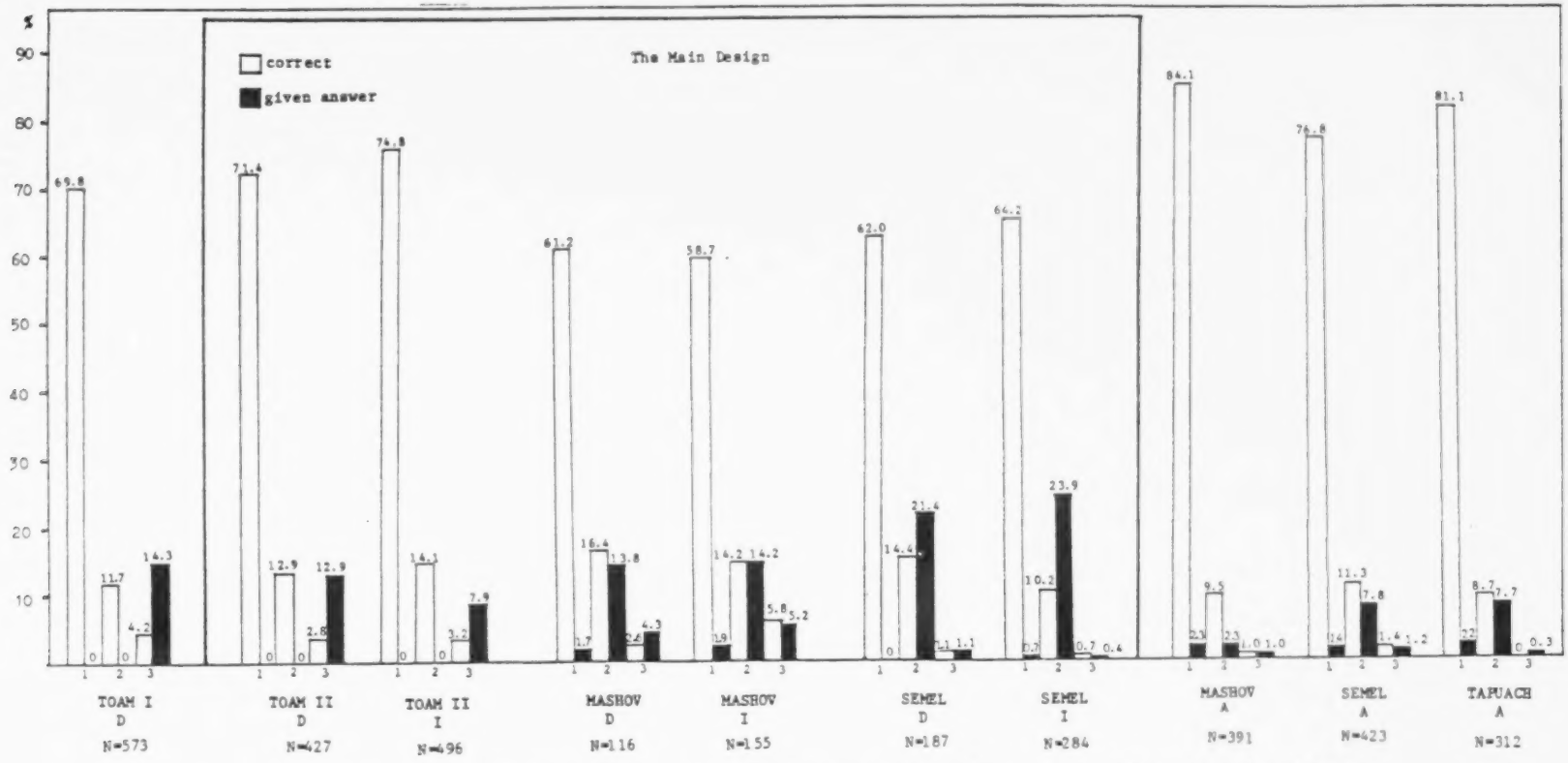
Because there were relatively few exercises which took 2-3 trials, we decided to average results at the level of system by school-type combinations rather than at the level of schools, and to combine the results over grade levels.

1. SUCCESS AND FAILURE OVER TRIALS

In this section we examine the pattern of percent success and of percent failure (the pupil is given the correct answer) as a function of trial. A trial is defined by three steps: computer presentation of the problem; the pupil's response; and computer presentation of feedback. The feedback can be 'correct' or 'incorrect'. If the answer is 'incorrect', the feedback can be accompanied or unaccompanied by a prompt, or by the correct answer. In the latter case, the process is completed. Otherwise, the pupil is given another opportunity to respond. In **Toam**, when an answer is multi-digit, the first incorrect digit entered results in an error message and a trial is defined. In the other systems, a trial is ended when the 'return' key is pressed and feedback presented.

Generally, the systems allow at most three opportunities to answer. In Figure 1 we present percent 'correct' and percent 'given answer' over three trials. Percent 'correct' is indicated by the unshaded columns and percent 'given answer' is indicated by the shaded columns for each of the three trials.

Figure 1: Percent 'correct' and percent 'given answer' over three trials.



D = disadvantaged schools I = integrated schools A = advantaged school

It can be seen that for all systems most of the pupils responded correctly on the first trial. If we compare systems in the main design, we see that **Toam** had the highest correct response rate (about 70% versus about 60% for **Mashov** and **Semel**).

Generally, within each of the systems the correct response rate on the first trial increased from disadvantaged schools to advantaged schools. However, the differences between disadvantaged and integrated schools were slight and for **Mashov** schools the disadvantaged schools scored slightly higher than integrated schools. The slight differences between disadvantaged schools and integrated schools is encouraging, since it indicates that the systems were adapting their presentation of materials to the level of the student. The greatest differences were found between advantaged and integrated **Mashov** schools (84% versus 59% respectively) and between advantaged and integrated **Semel** schools (77% versus 64% respectively).

After the first mistake, at most three percent of the pupils were given the correct answer. Nine to sixteen percent answered correctly on the second try. If the pupil again failed to answer correctly in **Mashov**, **Semel** and **Tapuach** he/she was most likely to be given the correct answer. From one to six percent of all the children answered correctly on the third try. Pupils who again failed were given the correct answer. The percent of children given the correct answer at some point was lowest for **Toam**. Among disadvantaged schools it was 13% for **Toam**, 20% for **Mashov** and 22% for **Semel**. Among integrated schools it was 8%, 21% and 25% respectively.

In summary, in **Toam** as opposed to **Mashov** and **Semel**, children were more likely to answer correctly on the first try and less likely to be given the answer at some point. For all systems excluding **Toam**, correct answers were most likely to be given after the second failure. For **Toam**, correct answers were only given after the third failure. There were only slight differences between disadvantaged and integrated schools, but in advantaged

schools pupils were much more likely to answer correctly on the first trial and were much less likely to be given the correct answer at some point.

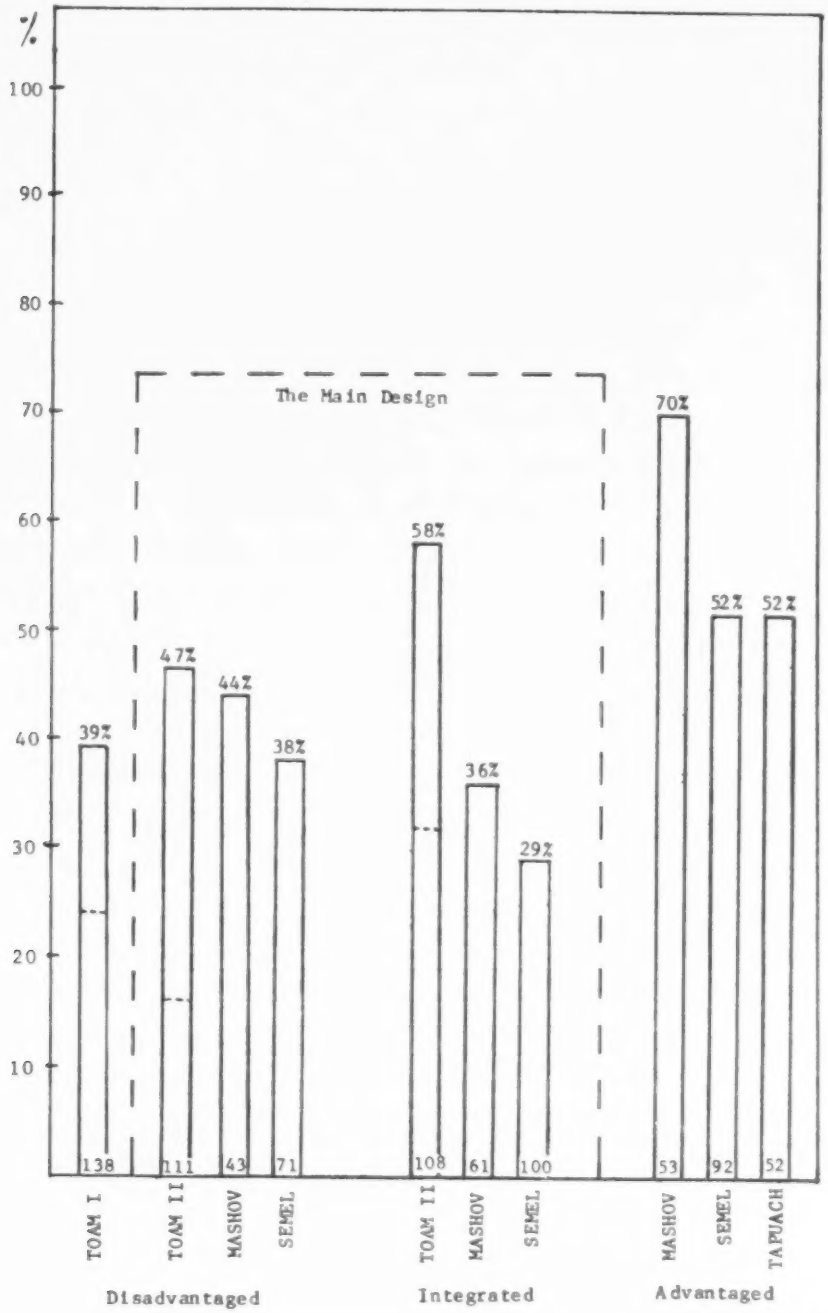
2. SELF CORRECTION

We turn now to "self-correction rate." This is defined as the percent of children who respond correctly **after** having answered incorrectly. In Figure 2 we present the percent correction after the first mistake, and after the second mistake (for **Toam** only).

For the schools in the main design it can be seen that self correction was most likely in **Toam** followed by **Mashov**, which in turn was followed by **Semel**. A result in this direction was to be expected since **Toam** provides much more explicit feedback than does **Mashov** or **Semel**. In **Toam**, as described in Chapter 2, responses are judged digit by digit as the pupil works through the problem. When an incorrect digit is entered the computer responds 'incorrect', indicating which digit is incorrect. Therefore, in many problems such as the four operations on multi-digit numbers, the pupils working with **Toam** are given an opportunity to correct the incorrect digit and continue on to complete the problem. In contrast, pupils working with **Semel** or **Mashov** enter the entire answer which is then evaluated. When a mistake has been made in a multi-digit answer, the pupil knows only that the answer is wrong and has no additional cues given to him as to which digit is incorrect.

Also, the trials for self correction are qualitatively different for **Toam** versus the other systems. In **Toam**, the pupil continues from where the mistake was made to completion of the problem. In the other systems, a correction trial constitutes a second attempt at solving the problem in its entirety. Here we have the additional confounding of the likelihood of a different mistake being made, the second or third time the problem is solved. This confounding cannot occur in **Toam** in that the pupil who makes a mistake is not required to start again from the beginning.

Figure 2: Percent correction after a mistake on the first attempt.*
And after the second mistake for Toam only - indicated by the dashed line.



* Toam correction rates do not include problems where 'time lapse' defined a trial.

We have no evidence as to the percentage of mistakes made on the second trial which were due to the instability of children's performance (for example, on the first trial the pupil correctly added 5 and 7 but forgot to carry, whereas on the second trial the pupil remembered to carry but incorrectly added). However, we use data obtained in math tests to estimate the degree of instability here. Bashi, et al (1981) found that when given the same problem twice on a standardized math test, between 16% to 19% of the pupils who answered the problem correctly the first time made a mistake when solving the problem the second time. This is surprisingly high and provides indirect evidence for explaining the higher self correction rates in **Toam**.

Though the results are in the expected direction, they are not completely clear cut. In integrated schools the **Toam** self correction rate was well above those of **Mashov** and **Semel**. However, in disadvantaged schools the **Toam** rate was only slightly above that of **Mashov**, and if one takes into account the results of **Toam** 1 schools the self correction rates in **Toam** and **Mashov** were about the same. A possible explanation for the finding is that a greater proportion of children in disadvantaged schools were completely lost in many problems and, as a result, were not helped by the prompting given in **Toam**.

Mashov also provides feedback in the form of hints for pupils who make a mistake. However, the hints are generally not as explicit as the prompts in **Toam** and are not provided on all problems (see Figure 3 on p. 75). Also, many of the hints are problematic, and in some cases reduced the problem to a trivial one (we discuss hints in detail in Chapter 8). For example, a pupil received the following problem:

	Fill in the correct symbol; < > or =
	$10 \times 10 \times 10 \; ? \; 10^3$
The pupil answered:	>
A hint appeared on the screen:	$10^3 = 10 \times 10 \times 10$
The pupil answered:	=

We feel that the utilization of hints explains the consistent differences in the correction rates for **Mashov** and **Semel**. **Mashov** correction rates were higher in both disadvantaged and integrated schools in the main design and in the additional analysis in advantaged schools.

We expected correction rates to be highest in advantaged schools and lowest in disadvantaged schools. The results were in this direction but not consistently so. For **Toam** the rate for integrated schools was about 58% versus about 43% for **Toam 1** and **Toam 2** disadvantaged schools. For **Mashov** and **Semel**, correction rates were clearly higher in advantaged schools, but they were lower in integrated schools than in disadvantaged schools.

We look now at correction rates after a second mistake. We do this for **Toam** only, since too few children working with **Mashov** and **Semel** received a third chance to correct their mistake. The correction rate after a second mistake was about 24% for **Toam 1**, 16% for **Toam 2** (disadvantaged schools) and 23% for **Toam 2** integrated schools. These are about half the correction rates after the first mistake and seem very low to us. We relate to this later in the discussion.

3. NON-CONSTRUCTIVE RESPONSES

In this section we examine two indicators of frustration or indifference. The first occurs when the child clearly enters a random or blind response. In this case he/she is observed pressing the keys blindly, without looking at which key is being pressed, or in the case of **Toam**'s membrane keyboard, the pupil starts at one end and slides his finger across all the numbers towards the other end of the keyboard, resulting in three very quick incorrect responses and the appearance of a new problem.

We view this indicator as a lower bound to the rate of random or blind responding since there were probably cases where the phenomena was not accompanied by clear, external signs.

The second indicator occurs when the pupil enters an answer that previously was evaluated as wrong by the computer. On rational grounds this should never occur. However, it does, and we feel that it indicates a serious break in communication. It could be a result of the child's doubts concerning the correctness of the computer's feedback, the child having no other idea for answering problem, or forgetting what he/she previously answered. The latter could be eliminated by having the pupil's wrong answer remain on the screen. As described in Chapter 2, the different systems act on a wrong answer differently. In **Toam** a mistake is erased almost instantaneously so that the digit entered may not be seen (the digit appears .5 seconds on the screen according to **Toam**). In **Mashov** and **Semel**, the pupil is informed that the answer is wrong and after approximately 3 seconds the mistake is erased. In **Tapuach** the student is informed of a mistake and the screen (with the mistake) does not change unless the pupil actively indicates that he is ready by pressing 'return'.

In Table 2 it can be seen that the phenomena of random or blind responding was rare on the first trial. It never occurred in **Semel** while in **Toam** and **Mashov** it constituted less than a percent of all problems. On the second trial the rate of occurence was higher (from 2% to 4% of all responses) and on the third trial (data for **Toam** only) it rose to 6.5% of all responses. The increase in percent occurrence over trials is not in itself an indication of increasing frustration since most pupils who responded blindly on the first trial continued to do so for the remaining trials, and the absolute number of pupils responding decreased over trials. On the basis of absolute numbers of blind responses by different children over trials, we do see signs of an increase over trials in **Mashov** and **Semel**. However, for **Toam** it is not clear.

In Table 2 we also present percent of responses on the second and third trials which were repeats of the previous response. The absolute sample sizes are smaller here since we were not always able to specify the exact response of the child. On the second trial the percent of responses which

Table 2: Blind responding and repeated mistakes.

1. Percent of blind or random answering as a function of trial and system.

	First Trial				Second Trial				Third Trial			
	No. of Problems	No. of Blind	% of Total	% of Mistakes	No. of Problems	No. of Blind	% of Total	% of Mistakes	No. of Problems	No. of Blind	% of Total	% of Mistakes
Toam	1125	6	0.5	1.4	420	10 (4)*	2.4	4.4	228	15 (7)**	6.6	8.5
Mashov	271	1	0.4	1.0	104	4 (3)*	3.8	6.3	-	-	-	-
Semel	471	0	0.0	0.0	171	3 (3)*	1.8	2.7	-	-	-	-

2. Percent of repeated mistakes as a function of trial and system.

	Second Trial				Third Trial			
	No. of Problems	No. of Repeat	% of Total	% of Mistakes	No. of Problems	No. of Repeat	% of Total	% of Mistakes
Toam	366	17	4.6	9.9	171	14	8.2	11.8
Mashov	99	2	2.0	3.4	-	-	-	-
Semel	164	24	14.6	22.2	-	-	-	-

3. Percent of either repeated mistakes or blind answering as a function of trial and system.

	Second Trial		Third Trial	
	% of Total	% of Mistakes	% of Total	% of Mistakes
Toam	6.9	14.2	14.7	20.3
Mashov	5.8	16.1	-	-
Semel	16.4	24.9	-	-

* Number of new, blind responses.

** Two children who had entered a blind response on the second trial did not do so on the third trial. There were 7 new, blind responses but only 5 more than the number in trial 2.

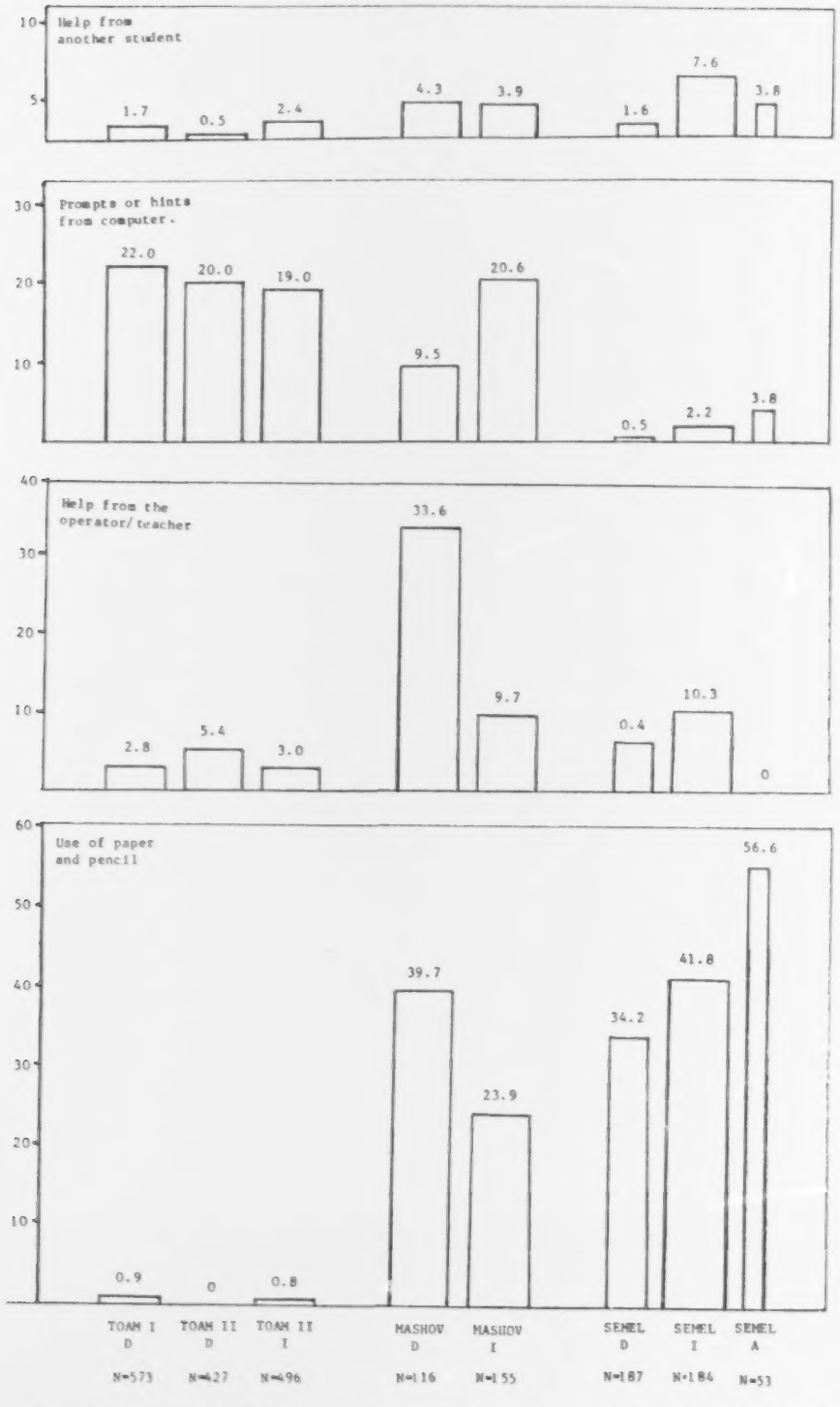
were repeats of previous mistakes was quite high for **Semel** as opposed to **Mashov** and **Toam**. Again we see the direction of differences among the systems as a reflection of the extent to which hints and prompts are used. However, the percent repetition for **Toam** seems high if one considers that the pupil does not have to reconstruct the entire answer (in multi-digit problems) but to replace the incorrect digit. This may be a result of the wrong answer appearing too briefly on the screen.

The percents of random or repeated responses shown in part 3 of Table 2 were quite high. Considering the fact that these were almost certainly under-estimates of the true rate, we are concerned that a significant proportion of the children were frustrated. We feel that this phenomonon could and should be reduced for all systems.

4. AUXILIARY SUPPORT

During the cycle of a single problem a child can utilize a number of resources: auxiliary materials (pencil and paper); teachers; other pupils; the computer (prompts or hints); or other (e.g. hand calculator, multiplication chart). For each problem observed, it was indicated whether or not each resource was utilized. In Figure 3 we present the percent of problems in which the above resources were utilized. For auxiliary materials, teacher support, and student support we obtained a similar pattern of results found for these variables in the activity observations presented previously. However, there is an important difference in the content of the data. Here, interactions with teachers and other pupils were clearly distinguished as being supportive and task orientated. The pupil was observed for a greater length of time and the observation was from the start through the completion of a problem. Because of this, the context in which the interaction took place was observed and consequently the content of the interaction more readily categorized (i.e. on-task interaction between students as opposed to inappropriate behavior).

Figure 3: Percent auxiliary help.



D = disadvantaged schools I = integrated schools A = advantaged school

It can be seen that teacher interaction was more prominent in **Mashov** in comparison to **Toam** and **Semel**. This may reflect the greater emphasis on problems involving concepts by **Mashov** (see next section). Also, there was virtually no teacher or pupil support in **Toam** as versus **Mashov** and **Semel** (occurring in about 5% of the problems). This could be seen as a successful reflection on **Toam**'s policy of utilization of time and independent work by the students, which is why the students work against the clock. Also, as described in the chapter on staff in the computer room (see Chapter 5), **Toam** stresses non-intervention by the teacher.

As for computer hints and prompting, **Mashov** and **Toam** stand out from **Semel**. As we mentioned, while **Toam** has no verbal hints, prompting does occur for all problems where the pupil is required to enter more than one digit. To estimate the percent of prompts for **Toam** we examined the percent of problems in which a mistake was made **and** the pupil was required to enter more than one digit. We found that prompting after a mistake occurred in 22%, 20% and 19% of the problems in **Toam** 1 disadvantaged, **Toam** 2 disadvantaged and **Toam** 2 integrated schools (about 72% of all problems observed were multi-digit).

5. A COMPARISON OF SYSTEMS ACCORDING TO TYPES OF PROBLEMS PRESENTED

In the previous sections we examined the patterns of correct versus incorrect responses and self-correction. We saw that self correction was highest in **Toam** followed by **Mashov** and in turn by **Semel**. We explained this in terms of the differences among the systems in use of prompts and hints. However, a different explanation may be possible: it may be that the systems were presenting different **kinds** of problems, e.g. an emphasis on fractions in one system versus an emphasis on whole numbers in another.

We did not deal with content first, because we feel that computer-child interactions are interesting in their own right and we wanted to compare work patterns irrespective of specific content.

The nature of computer-child interactions makes the examination of content especially difficult. At any point in time, children are working at different levels of difficulty and in different strands or lessons. Conceivably, the types of problems being worked on change as a function of grade level, type of school and the period of the academic year. It is true that in **Semel** and **Toam** the structure according to strands and a policy which moves children from strand to strand guarantees some form of stability in patterns but, the extent to which children work in one strand or another very much depends on their relative difficulties within the strands. **Mashov**, on the other hand, is organized according to a progression of lessons on various aspects of the curriculum and children follow similar paths but possibly at very different rates. Therefore, depending on the degree of changes in topics along the way, children in different classes, grades, or schools could be working on very different topics. As a result, we were not sure of what to expect in a content analysis and approached it reluctantly to say the least.

In Figure 4 we show the percent of problems in grades 4 and 5* according to eight broad categories (see page 64); the four operations with numbers up to 100, the four operations with numbers greater than 100, problems involving mathematical concepts, word problems, problems with simple fractions, problems with decimal numbers, problems with negative numbers and problems with exponentials.

In Figure 4, the first bar (in each block) represents percent of problems in the first two categories (problems involving the 4 operations). The area below the dashed line represents the percent of problems with numbers up to 100 and the area above the dashed line represents the percent of problems with numbers greater than 100.

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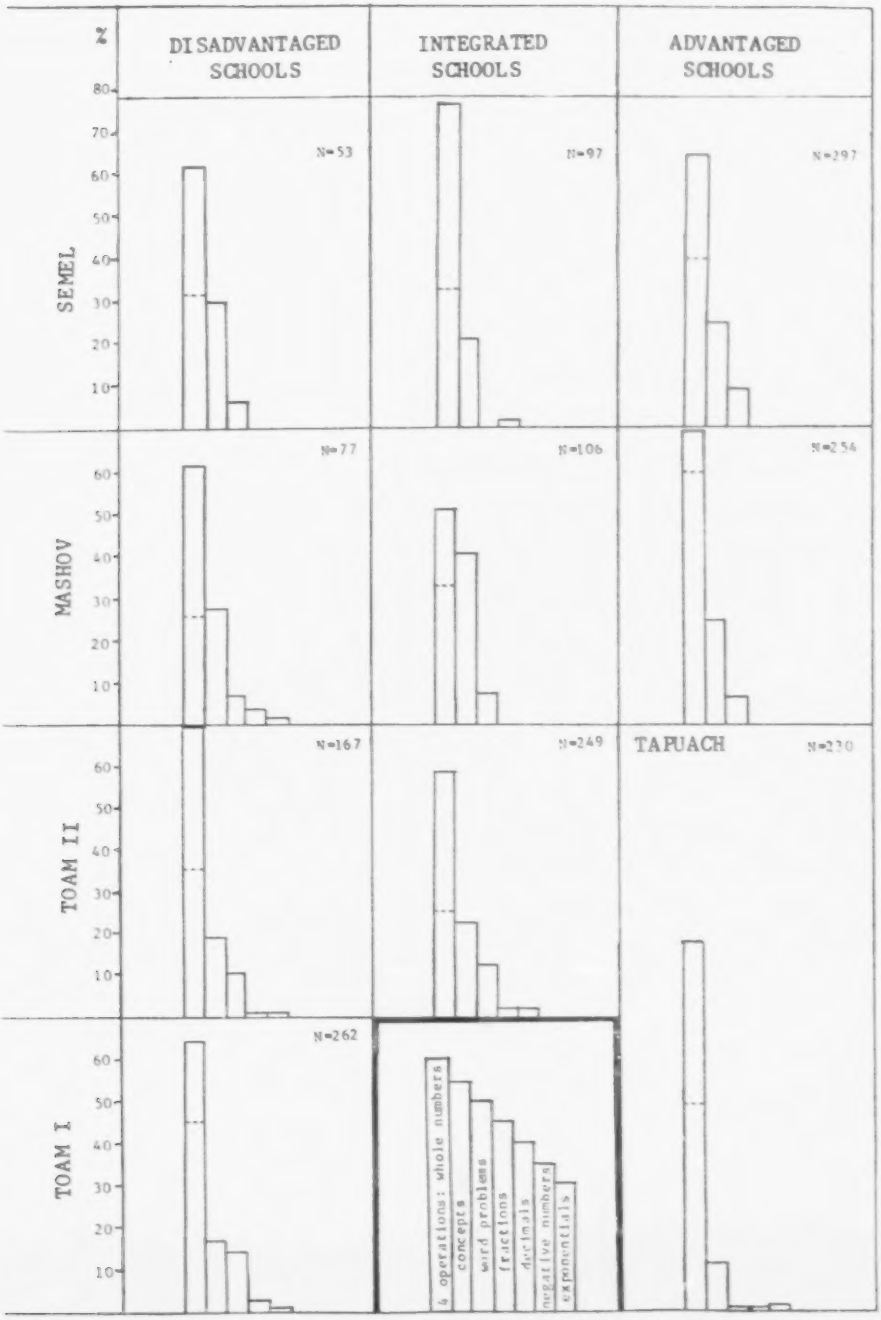
* Because curricula changes with grade level, we split the sample into two groups for these analyses: grades 4 and 5, and grades 6 and 7.

Figure 4: Percent of problems observed in grades 4 and 5 by categories.*



The area below the dashed line represents the percent of problems with numbers up to 100. The area above reprsents the percent of problems with numbers greater than 100.

Firstly, it is seen that for all systems and all types of schools the four operations with whole numbers predominated, followed by concepts. In all but two cases, the third most prevalent problem type was word problems. But, this type of problem was always less than 10% in **Semel** and **Mashov** and between 10% to 15% in **Toam**. The remaining problem types (fractions, decimals, negative numbers and exponentials) rarely occurred in any of the systems.

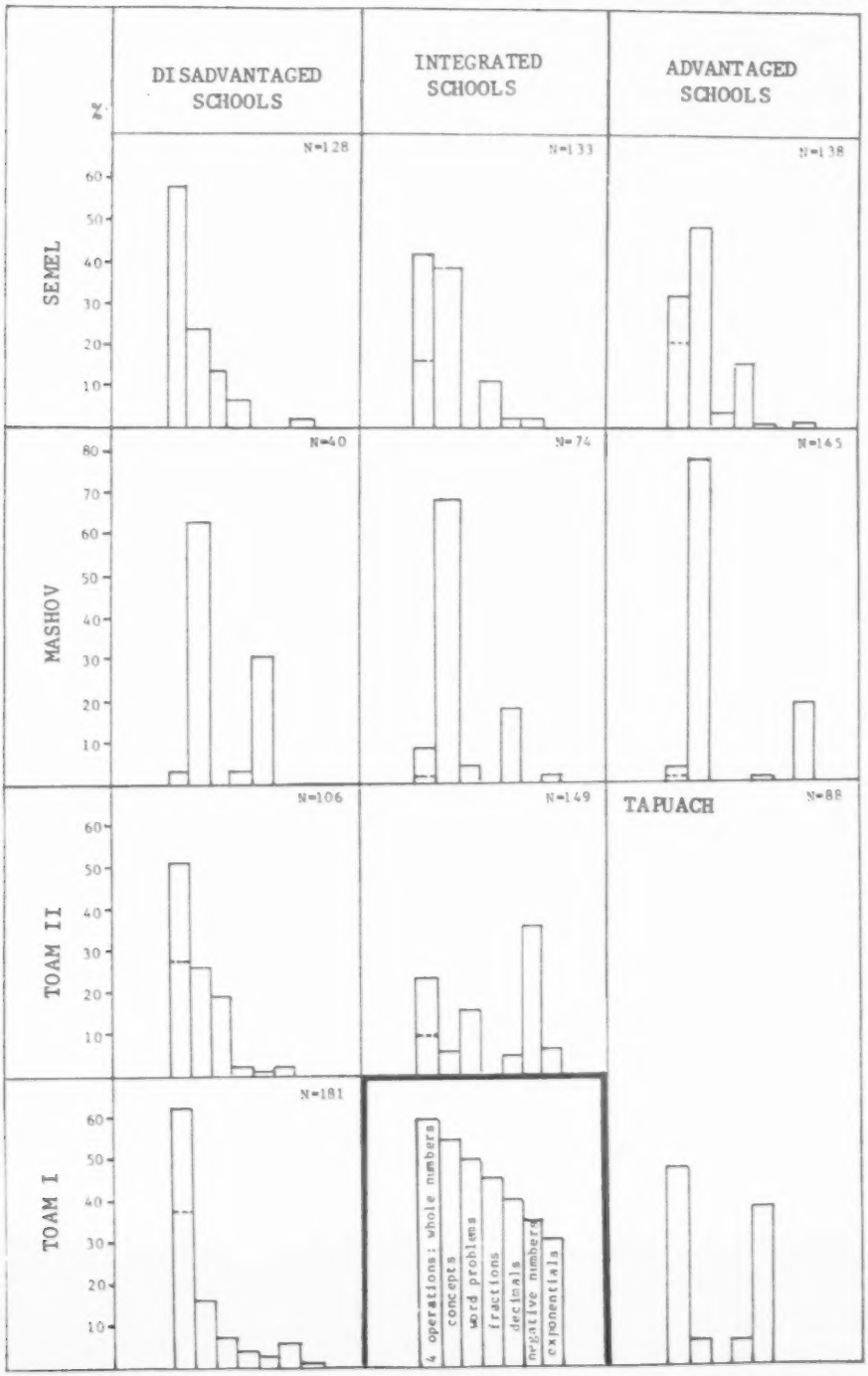
One can also point to some interesting differences. For example, **Tapuach** had the most extreme emphasis on the four operations. This is interesting since this system is most dependent on teacher decisions. **Toam** and **Tapuach** had relatively few problems involving mathematical concepts (20% and 10% respectively) compared to **Mashov** and **Semel** (25% to 40% for **Mashov** and 22% to 30% for **Semel**).

However, the overriding pattern was clear and consistent across systems and school types. Most problems were the four operations on whole numbers, followed by concepts and word problems.

In grades 6 and 7 (Figure 5), **Toam** and **Semel** disadvantaged schools largely maintained the pattern found in grades 4 and 5 but there was somewhat less emphasis on operations with whole numbers and a greater emphasis on fractions, decimals, negative numbers and exponentials (but still below the 10% level).

However, in integrated and advantaged **Semel** schools, the emphasis shifted from whole numbers to mathematical concepts. While in disadvantaged schools the emphasis on the four operations was 57% versus 23% for concepts. In integrated schools the corresponding figures were 41% versus 39% and in advantaged schools they were 34% versus 50%.

Figure 5: Percent of problems observed in grades 6 and 7 by categories.*



The area below the dashed line represents the percent of problems with numbers up to 100. The area above reprsents the percent of problems with numbers greater than 100.

A similar change occurred in **Toam** schools. The emphasis on the four operations of whole numbers dropped from 51% in disadvantaged schools to 24% in integrated schools. However, the slack was not taken up by concepts but rather with a large emphasis on the four operations with negative numbers.

The difference between types of problems at grades 4 and 5 and grades 6 and 7 was most pronounced in **Mashov**. In grades 6 and 7 there were virtually no problems involving the four operations with whole numbers and instead concepts were the predominant problem type in all schools (62% in disadvantaged schools, 68% in integrated schools and 77% in the advantaged school). Also, problems with decimal numbers were strongly represented in the disadvantaged and integrated schools and exponentials in the advantaged schools.

In **Tapuach**, the predominance of the four operations with whole numbers found in grades 4 and 5 was greatly reduced and much emphasis was placed on problems with decimal numbers.

We see then, that for **Toam** and **Semel**, sixth-seventh grade children in disadvantaged schools were working on similar types of problems as fourth-fifth grade children in general. However, in other cases the pattern changed from an emphasis on operations of whole numbers in Grades 4-5 to an emphasis on concepts, decimals, negative numbers and exponentials in Grades 6-7.

6. A COMPARISON OF RESPONSE PATTERNS FOR WHOLE NUMBER OPERATIONS AND CONCEPTS

We now look at the distribution of percent of correct answers as a function of trial for problems involving the four operations on whole numbers and for problems involving mathematical concepts separately. These two problem types were examined because they constituted the bulk of the problems and there were too few other problem types to allow further investigation.

Table 3: Percent 'self-correction' by trial as a function of problem type.*

System	Response by Trial** / Problem Type	First Trial			Second Trial			Third Trial	
		Right	W-ans	W-again	Right	W-ans	W-again	Right	W-ans
Tzam II Disadvantaged	4 operations (whole numbers) N=277	73.65 204	-	26.35 73	10.11 (38.36) 28	-	16.25 (61.64) 45	3.61 (22.22) 10	12.64 (77.77) 35
	concepts N= 84	71.43 60	-	28.57 24	15.48 (54.18) 13	-	13.10 (45.85) 11	0	13.10 (100.0) 11
Tzam II Integrated	4 operations (whole numbers) N=267	75.66 202	-	24.34 65	13.11 (53.85) 35	-	11.24 (46.15) 30	3.75 (33.33) 10	7.49 (66.66) 20
	concepts N=122	76.23 93	-	23.77 29	15.57 (65.50) 19	-	8.20 (33.50) 10	3.28 (40.00) 4	4.92 (60.00) 6
Mashov Disadvantaged	4 operations (whole numbers) N= 49	65.31 32	2.04 1	32.65 16	12.24 (37.50) 6	16.33 (50.00) 8	4.08 (12.50) 2	2.04 (50.00) 1	2.04 (50.00) 1
	concepts N= 49	55.10 27	2.04 1	42.86 21	20.41 (47.62) 10	12.24 (28.56) 6	10.20 (23.80) 5	4.08 (40.00) 2	6.12 (60.00) 3
Mashov Integrated	4 operations (whole numbers) N= 50	56.00 28	4.00 2	40.00 20	6.00 (15.00) 3	20.00 (50.00) 10	14.00 (35.00) 7	8.00 (57.14) 4	6.00 (42.86) 3
	concepts N= 83	65.06 54	1.20 1	33.73 28	15.66 (46.43) 13	10.84 (32.14) 9	7.23 (21.43) 6	3.61 (50.00) 3	3.61 (50.00) 3
Semel Disadvantaged	4 operations (whole numbers) N=107	62.62 67	-	37.38 40	14.95 (40.00) 16	20.56 (55.00) 22	1.87 (5.00) 2	0.93 (50.00) 1	0.93 (50.00) 1
	concepts N= 51	68.63 35	-	31.37 16	11.76 (37.49) 6	19.61 (62.51) 10	-	-	-
Semel Integrated	4 operations (whole numbers) N=172	62.21 107	-	37.79 65	11.63 (30.77) 20	25.58 (67.92) 44	0.58 (1.54) 1	0.58 (100.0) 1	0
	concepts N= 85	76.06 57	1.18 1	31.76 27	9.41 (29.63) 8	22.35 (70.37) 19	-	-	-

* The first row of each cell shows the percent out of all responses. The second row shows the percent out of those attempting to correct the previous mistake.

** **Right** = Percent correct.
W-ans = Percent given answer after incorrect response.
W-again = Percent given another trial after incorrect response.

In Table 3 it can be seen that the distribution of percent self-correction within systems was highly similar for the two types of problems. This can be seen as an indication that the differences observed among systems in the patterns of correct responses were not due to differences in problem types.

8. AN EXAMINATION OF PUPILS WITH DIFFICULTIES*

In this chapter we describe the main phenomena found in observation - interviews of pupils having difficulties with computer based drill and practice. The observations were natural in the sense that they took place in the normal framework of computer rooms. However, the natural process was disturbed from time to time by the observer and thus turned into a 3-participant dialogue (the observer, the pupil and the computer).

We emphasize that the following findings concern only pupils who were having difficulties with the drill and practice. We have no estimate of the percentage of these pupils, but hope to obtain one in a future stage of our research. Theoretically the percentage should be very low because the difficulty level is determined by the computer according to the pupil's ability. Our impression is that, in fact, the percentage is far from negligible.

In most of the situations the computer did not explain the concepts to the pupils. In Mashov there were some attempts here and there to introduce concepts to the pupil and also to provide clues when the pupil had difficulties. It is not clear at all whether these were successful. Usually when a pupil failed two or three times the correct answer was presented by the computer (see Chapter 7).

The protocols presented in this chapter are based on 12 hours of observation in two Toam schools (grades 3-6); 9 hours of observation in two Mashov schools (grades 4 and 6); and 5 hours of observation in one Semel school (grades 4-6). These were independent of the observations described in the previous chapters. However, it should be noted that the phenomena reported here were also detected in those observations.

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1. THE PROBLEM

When pupils are having difficulties in computer drill and practice, the main question raised is the following: If the pupil's answer is incorrect and the mistake is not "clerical" how can the pupil do better on the second trial? In other words, how can a correction procedure occur if there is no explanation about the character of the mistake? A possible answer is that the feedback causes the pupil to re-think the given task, to analyze it carefully, to understand it and thus to arrive at the right answer. Theoretically this is possible. Our impression, nevertheless, is that the drill and practice programs we observed provide an example of the widespread phenomenon of **learning without understanding**, a phenomenon that has drawn the attention of several researchers in Mathematics Education in recent years. Two well-known examples of this are Erlwanger (1973) and Rosnick and Clement (1980). Erlwanger (1973) observed a fifth grader, Benny, who wrote 2/10, 5/10 and 4/11 as the decimals 1.2, 1.5 and 1.5 respectively (he added the numerator and the denominator and then added a decimal point). On the other hand, Benny managed to get through the IPI (Individualized Paced Instruction) Mathematics course and was considered an above average pupil. How did he do it? Benny claimed that he found a method for answering the IPI questions. He answered the questions according to this and hid his own mathematical views about the correct answers.

Rosnick and Clement dealt with the following question given to a group of first year engineering majors: Write an equation using the variables S and P to represent the following statement: "There are six times as many students as professors at this university. Use S for the number of students and P for the number of professors." Only 63% were able to answer it correctly and only 27% correctly answered a similar but more complicated problem. The common mistake was P = 6S (the reversal mistake). Remedial teaching was tried but it turned out that "although the surface behavior of the students changed, continued probing in the interviews revealed that many of the students' misconceptions remained unchanged" (Rosnick and

Clement, 1980, p. 3). Again, how could the surface behavior improve without understanding? An interview with a student (p. 75) gives a partial answer to this question. Essentially, the following happens: After reading the students and the professors problem, the student's impulse is to write P = 6S but, because of the remedial teaching he received, he knows that this is wrong. Therefore, he changes it and writes: 6P = S. This is the kind of strategy students often use to get the right answer.

Rosnick and Clement claim that "large numbers of students may be slipping through their education with good grades and little learning" (p. 24). They ask: "How can students learn to solve these problems with understanding?" (p. 23). It is of course a very important question. But there is also another question: "How can students learn to solve these problems **without** understanding?"

We will try to answer this question, at least partially, in the context of computer based drill and practice. We must emphasize, however, that the phenomenon of learning without understanding exists in many domains and situations, not only in computer based drill and practice in Arithmetic. Also, our interpretations of the interaction protocols might be viewed by some as going far beyond the data, or even as speculation. We are well aware of the difficulties of dealing with "case-studies," but their importance for deeper understanding of educational phenonena should not be denied. (There has been a great increase in the use of case studies in evaluation research in recent years). Also, we argue that our interpretations are the most plausible for the data presented and, in addition, are congruent with other independently obtained data and interpretations (e.g., Erlwanger, 1972; Rosnick and Clement, 1980).

2. THE PROTOCOLS

As we said before, a pupil who does not understand the concepts involved in a given problem is unlikely to be helped by the simplistic correct-incorrect feedback provided by the drill and practice programs.

After two or three failures the computer provides the right answer, and he/she will naturally try to use it in order to be successful in the future. As a result he/she is likely to develop solution strategies for similar problems which are not based on understanding. For instance, the following question was posed to a pupil by the computer: "One-quarter of a number is 5. What is the number?" Questions posed to the pupil by the observer revealed that the pupil did not know the concept of "a quarter" (he did not succeed in coloring a quarter of a given shape and could not specify a quarter of a given set). After two failures the right answer was given by the computer: 20. The pupil, lacking understanding, would naturally examine the relationships among the numbers in the problem (which are 1,4,5) and the answer (20). An obvious relationship is 5x4=20 and we surmise that he concluded that in order to get the right answer to problems similar to the one above he should multiply the numbers which are different than 1. Using this strategy on similarly phrased problems he was successful and the computer passed him to a higher level of difficulty where he will probably try the same approach.

The types of computer drill we observed encourage trial and error responding based on superficial aspects of the problems. A pupil who does not know how to answer a given exercise still has two or three chances to answer correctly. The trial is based on the assumption that one should perform certain arithmetical operations on the numbers given in the problem (whether a word problem or an exercise). In many cases the number of the arithmetical operations needed to solve the problem is one and there are only two candidates. Thus, the pupil could arrive at the right answer after the second trial, at most. It is true that some of the computer programs do not give credit to answers given after the first trial, but, in cases such as the above, the pupil will correctly answer similarly phrased problems on the first trial.

We use the following protocols to demonstrate these points. They are based on observations of three Israeli computer drill and practice programs. We note that the examples presented here were taken from a pool of events that

occurred in many different computer rooms and all of them have similar patterns. We did not cite additional examples here to avoid repetition. We, at this stage, cannot tell the exact percentage of pupils having the described difficulties. However, we are sure that these are phenomena that cannot be ignored. For most examples, we will not identify the systems since our aim is to point out general phenomena. In the following we will denote the computer by C, the pupil by P and the interviewer by I.

(1) C: "Which number is greater than 4 by 7?"
P: (third grade): "3."
C: "You are wrong."
I: "What did you do? Explain it to me!"
P: "I thought what the difference was."
I: "What is the difference between what?"
P: "Between 7 and 4."
I: "What was the question?"
P: "Which number is greater than 4...?"
I: "By 7."
P: "I don't understand it."
I: "...Do you know, perhaps, which number is greater than 1 by 2?"
P: "Of course!"
I: "Which?"
P: "1"
I: "...Again you are calculating the difference...What does it mean, for instance, that 5 is greater than 3 by 2?"
P: "...7 plus 4!"
I: "...Alright, try it!"
P: "I make it 11."
C: "This time you are right."

An analysis of the above conversation shows that the pupil did not understand the phrase: "a number greater than y by x". He even admitted it explicitly ("I do not understand it") and showed it again when the interviewer posed another example with simpler numbers ("a number greater than 1 by 2"). Probably the pupil knew the phrase: " by what number is x greater than the number y?" He knew also that the answer to this question is given by x-y. This is probably the reason why he calculated 7-4 and 2-1. When he saw that this strategy did not lead him to the right answer, he looked for another strategy. But how could he look for another strategy if he did not understand the question? It turns out that by the trial and error method it was quite easy. The exercise presented two numbers. It was quite clear to the pupil that he had to act on them by means of a certain arithmetical operation. In the first trial he subtracted them. In the second trial he added them and obtained the right answer. The pupil ignored the question posed by the interviewer: "what does it mean that 5 is greater than 2 by 3?" and also the opportunity to understand it. We feel that this was because he was bent on finding any arithmetical operation which would lead to the right answer. Later, for similarly phrased excercises he/she is likely to guess immediately that the two numbers should be added.

One can argue that without understanding a question it is impossible to identify similar questions and to remember how to solve them. Practice, however, does not confirm this view. Pupils can easily identify the structure of the problems and remember their method of solution. The reinforcement they receive from the computer may even make them believe that they do understand the subject, although the Mathematics educator is reluctant to call it understanding.

(2) C: "$^{3}/_{10} + {}^{1}/_{5} = {}^{?}/_{10}$"
P (grade 6): "..."
I: "How do you add fractions?"
P: "I do not know what to write."

I: "Do you know how to add fractions?"

P: "I do 3 plus 1, don't I?"

I: "Do you want to try (to type it) or to discuss it?"

P: "... 7."

I: "How:...Why? ...How did you get 7?"

P: "I think that 10 is the common denominator."

I: "Alright, and how will you find the numerator?"

P: "10 divided by 10, isn't it?"

I: "Do you divide 10 by 10 because there is 10 on the right side?"

P: "Yes."

I: "So, you divided 10 by 10. What did you get?"

P: "It is 1."

I: "Yes."

P: ... (pointing at the numerator of the first fraction) it is 3."

I: "Yes."

P: "10 divided by 5 is 2 ... 3 ... it is 5, isn't it?"

I: "Yes... tell me, how did you get 7 a minute ago? Do you remember?"

P: "It wasn't my day."

The situation here is different from the previous one, where only two numbers were presented to the pupil and he had to select the operation leading to the right answer. Since multiplication and division were not likely candidates for that type of question, the pupil could easily derive a rule for obtaining the correct answer. In this example, on the other hand, five numbers were presented to the pupil (we consider the numerator and the denominator of each fraction as two different numbers). It seems that if the child did not know how to add fractions at the first stage he would not be able to reconstruct the addition algorithm for fractions. But here also, as in the previous case, he succeeded in arriving at the right answer with the help of a few hints. In the beginning he made a common

mistake in adding fractions. He added the numerators and ignored the fact that the denominators were different (very often the mistake is to add a numerator to a numerator and a denominator to a denominator but here the denominator of the result was determined by the computer). After that, the pupil recalled a bit of the addition algorithm for fractions. Probably, he divided 10 (the common denominator) by 5 (the denominator of the second fraction at the left) and added the result to 5 (the denominator). This probably explains how he got 7 (this type of "strange" error is explained in Vinner, Hershkowitz and Bruckheimer, 1981). The next attempt already put the pupil on the right track.

Note the pupil's reaction to the question: "How did you get 7?" He answered : "It wasn't my day" as if it were a matter of chance. This, perhaps, reflects the pupil's point of view about the process of getting the right answer: There are several ad hoc strategies to deal with such exercises and he has to choose one of them.

(3) C: "Dalia had 11 beads. She bought 5 beads but 7 got lost. How many beads has Dalia now?"
P: (third grade): "11 minus 7."
I: "Why did you do 11 minus 7?"
P: "Because she got the beads and afterwards she lost 7 ... it is 11 minus 5."
I: "Why minus 5? ... Let us read the question once more."
P: "Dalia had 11 beads. She bought 5 beads but 7 got lost. How many beads has Dalia now?"
I: "You saw there 7 and 5 and what did you do?"
P: "It is 6."
I: "How did you get it?"
P: "11 minus 5."
I: "Then what about the 7? ...There are three numbers in the question: 11, 5 and 7. Why did you do 11 minus 5?"
P: (after a long silence): "Because she lost 7."

I: "So why did you do 11 minus 5?"

P: "Because she got 11 beads and afterwards she got 5 more... Ah! 11 plus 5 minus 7!" (she calculates 11 + 5 - 7 and types 9).

C: "Very good."

P: "How long it took me to discover it."

This description is typical of a pupil who has difficulties in word problems. The goal which directed him at the first stage was to find a suitable operation to be carried out on two numbers. The fact that three numbers were given here did not disturb him too much at the beginning (it confused him a lot later on). The key for the selection of the operation at the first stage was a verbal one (see for instance Nesher and Tuval, 1975). In this question it was the word "lost". When this word appears it is well known that one should subtract. But to subtract what from what? Of course, one should subtract a small number from a larger number. Since it was said that "7 got lost" the answer "11 minus 7" is quite expected. This was also explicitly expressed by the pupil: "She got the beads and afterwards she lost 7". However, another look at the question showed the pupil that the number 5 also appeared in it. Therefore comes the trial: 11 minus 5. Apparently, the pupil systematically responded to the most dominant stimulus at the moment. In the beginning, it was the expression: "7 got lost." Afterwards, the discovery that the number 5 also appeared in the question made it the most dominant stimulus. When the last trial was also questioned by the interviewer the pupil returned to the starting point: "because she lost 7." He did not know to which stimulus he should react now and his answer had no relevance to the question: "why 11 - 5?" After the question was repeated the pupil reconsidered the problem and reformulated it in his own words. Now he could see all its components simultaneously. It is a kind of illumination in the sense of the Gestalt Psychology. Note that it was preceded by almost blind trial and error responding. As in the previous example it is worthwhile noting the pupil's last comment ("how long it took me to discover it").

(4) C: "A pair of trousers costs 45 shekels and a shirt costs 9 shekels. How many shirts did Mom buy if she paid 81 shekels for the shirts and for one pair of trousers?"

P: (Sixth grade): "9"

I: "Why?"

P: "Because 9 times 9 is 81."

I: "Try it."

P: (types 9)

C: "You are wrong. Try again."

P: "5"

I: "Why?"

P: "Because 5 times 9 is 45."

Here the pupil was misled by the numbers. He looked for an arithmetical operation to be performed on two numbers. The last two numbers that he read suggested division. Failure did not make him change his approach. Again he looked for an arithmetical operation between two numbers and the candidates were the first two numbers. The strategy of trial and error is not always successful. Without explicit feedback there is probably no way to make most pupils abandon non-constructive guessing of the sort we see here.

(5) I: "Please read the question the moment it appears on the computer" (this is done for the sake of recording).

P: (second grade): "4 children went to the swimming pool in the morning, 3 children went to the swimming pool in the afternoon. Ah! It is ..."

I: "Are you already going to answer it?"

P: "7."

I: "But you haven't finished reading the question ("how many children went to the pool that day?")"

P: "But I know."

I: "How do you know?"

P: "Because I have had something like that many times."

In this question, contrary to the previous one, there were no obvious verbal cues. In spite of that, there was something in the question and previous questions which led the pupil to the solution without reading the end of the question. Our claim is that this "something" is the **surface structure** of the question; structure in the sense of Gestalt theory. Since we speak about a structure that one grasps **globally and not analytically** it is hard to characterize it and to describe its components. (We use the word "structure" as a primary notion, in the same sense it has in Gestalt theory.) Without the above claim it is hard to explain how pupils solve problems which they only partially understand. It is obvious that verbal and numerical cues are not enough to explain it.

(By numerical cues we mean anything which leads the pupil to choose an arithmetical operation which depends mainly on the numbers given in the word problem. For instance, if two numbers in a word problem are about the same size, then they are likely to be added or the smaller number is likely to be subtracted from the larger number. If one number is much less than the second number, then one is likely to multiply or divide by it.)

The surface structure as a factor determining the choice of the arithmetical operation when solving a word problem can be illustrated by the following example:

(6) C: "The mailman delivered 5 letters on Bialik Street. On Herzel Street he delivered 7 letters and on Burla Street he delivered 8 letters. How many letters did he deliver?"

P. "20."

I: "How did you get it?"

P: "5 plus 7 plus 8."

I: (after 15 minutes): "The mailman delivered 4 letters on Bialik Street. On Herzel Street he did not find the address of 3 letters. On Burla Street he delivered 11 letters. How many letters did he deliver?"

P: "18."

I: "How did you get it?"

P: "4 plus 3 plus 11."

From the pupil's point of view the two questions had the same surface structure. This surface structure (Gestalt) was grasped globally, without any analysis. It then "called" the arithmetical operation which was carried out on the numbers in the problem.

We note again that the above examples are not exclusive to computer based drill and practice. However, they are typical to it when children with difficulties are involved. The fact is that these children have been put in a situation where there is no way to overcome their conceptual difficulties and this leads them to look for ways to produce the right answers in anyway possible. This is almost exclusive to this kind of drill and practice. In other situations, at least theoretically, there is a chance for constructive interactions to occur. In fact, we argue later that the drill and practice programs we observed could be revised to include response-specific feedback and that this would be a good start toward such constructive interactions. In some of the above examples we saw types of interactions which might help students (namely, interactions similar to those they had with the interviewer).

In addition to the phenomenon described above for all systems, the Mashov system presented problems and hints in ways which defeated their purpose. Following are three examples.

In Mashov hints are occasionally provided for students who fail in their first or second trial. Unfortunately these apparently were not well thought-out and tested. As a result, some of them are quite useless. Even worse, they can cause anger and frustration in the child. We present two examples of this.

I. The following question was posed to a pupil: "The price of a notebook is 9 shekels. What is the price of 4 notebooks?" The pupil multiplied 9 by 4 and got 34. He typed his answer and the computer responded that he was wrong. After another trial with the same answer the computer provided the following hint: "The aritmetical operation which you have to carry out is multiplication." It is hard to guess what the child thought about the computer when he got such a hint, but we should not be surprised if he was frustrated.

II. On the computer screen the following was written:

1/10 represents tenths
1/100 represents hundredths
1/1000 represents _____?

The pupil typed: "thousandth." (Note that 's' is missing.) The computer responded: "error." The pupil typed his answer again and the computer reacted the same way and gave the following hint: "Note that the numbers decrease by 10." The desperate pupil typed again: "thousandth." After the third try the computer provided the right answer: thousandths. The hint defeated its purpose and the rigidity of the program, is in this case, short-sighted.

The purpose of some Mashov items was to have the pupils solve a given exercise in one particular way and not in another. There is no point in certain exercises if they are not worked out the way they were intended. For example:

I. A pupil got the exercise: 55 x 12. The intention was that the pupil would practice multiplication either mentally in the form:

$$55 \times 12 = 55 \times 10 + 55 \times 2$$

or by means of the column algorithm:

$$\begin{array}{r} 55 \\ \times\ 12 \\ \hline 110 \\ 55 \\ \hline 660 \end{array}$$

The pupil raised his hand for two minutes, but the teacher was busy. Finally the pupil gave up and carried out the computation on paper as follows:

$$\begin{array}{r} 110 \\ 110 \\ 110 \\ 110 \\ \underline{110} \\ 660 \end{array}$$

No doubt that this is the right solution. Even more, the meaning of multiplication was clear to the pupil. But the pupil must also learn multiplication techniques, something which he missed here.

II. Another pupil got the sequence:

$$(35:5) \times 5 =$$
$$(65:5) \times 5 =$$
$$(40:5) \times 5 =$$
$$(45:5) \times 5 =$$

The intention, of course, is that the pupil notice that division by 5 and multiplication by 5 cancel each other. In all four cases the pupil calculated the result of the division by 5 and then multiplied by 5. The final results were correct, but the point of the exercise was not conveyed to the child.

In both of the above cases, simple feedback would have helped. For example, in the latter case, the feedback for a correct response might have been: "Great, you got the correct answer, I hope you noticed that the multiplication by five and the division by five cancel each other. This saves a lot of work."

Sometimes a sequence of exercises is given to the child. At the end or by the end of the sequence, the child is supposed to make a generalization summing up his experience with the sequence. But very often these generalizations do not occur. The last example of the previous section could be used in this section as well. The pupil did not notice by the end of the sequence that for every A, (A:5) x 5 = A. In another example, the following sequence was presented to the pupil:

4 is ___?___ times greater than 2. 4^2 is ___?___ times greater than 2^2.
6 is ___?___ times greater than 2. 6^2 is ___?___ times greater than 2^2.
9 is ___?___ times greater than 3. 9^2 is ___?___ times greater than 3^2.
8 is ___?___ times greater than 2. 8^2 is ___?___ times greater than 2^2.

The observer noted that in each exercise the pupil carried out all the computations and then typed the answer. It was intended that he would discover that, if A is K times greater than B, then A^2 is K^2 times greater than B^2. A short discussion with the pupil revealed that this idea had not occurred to him. He did not even see the structure common to the four exercises. Again, relatively simple feedback might have helped.

3. Discussion

The ability to provide varied, personal and immediate feedback is considered to be one of the greatest advantages of the computer. Unfortunately, as we saw above, this facility is poorly utilized in the programs examined. Generally, when a mistake is made, the computer does not explain to the child why his answer is incorrect. It only notes the mistake (this is like a teacher marking the mistakes in a homework assignment without explaining how to solve it correctly or why the answer is incorrect). If the basis of the mistake is conceptual, then the pupil has to grope in the dark for the correct answer. This groping may not advance the student. The first example (sec. 2) demonstrates it very well (One-quarter of a number is 5. What is the number?). On the basis of the correct answer given by the computer, the child can construct an ad hoc

algorithm for solving similar exercises and thus advance to a higher level of exercises. The benefit to the child's conceptual development is quite doubtful. In addition, the ability of the teacher to use the feedback provided by the computer is limited by two factors: 1) the pupils can arrive at correct answers without understanding the concepts involved; and 2) if the computer indicates that a pupil is having difficulty at a specific level, the reason for it is unknown and the teacher has to find its source. So the report is only a starting point.

Computer based drill and practice in schools are perhaps the embodiment of Skinner's ideas about learning machines. On page VII of Holland and Skinner (1961) one can find: "The teaching machine presents each item automatically. The student writes his response on a strip of paper revealed through a window in the machine. He then operates the machine to make his written response inaccessible, though visible, and to uncover the correct response for comparison."

However, only one of the programs we have observed seriously implements the above suggestion and none of them meets the requirement on p. VI, which is: "Items are so constructed that the student must comprehend the critical point in order to supply the answer." So, the behavioristic requirements from learning machines are not met by the programs we observed.

According to the behaviorist approach, to understand a subject is to be able to answer a list of questions on that subject. Ausubel, the spokesman of "meaningful learning," relates to this problem when he deals with Skinner, one of the most radical behaviorists (Ausubel, 1967, p. 66): "Skinner denies that the concept of meaning is necessary or useful in explaining behavior. He is completely unconcerned with the problem of whether an emitted verbal response represents the stimulus that comes to elicit it. The problem of how meaning is learned is thus solved by the denying that meaning exists."

This paragraph demonstrates a major problem in the question and answer system in the educational process and especially in questions and answers by means of computers. There is no need to say that we do not share the behavioristic approach to learning. As non-behavioristic educators we are interested in children's thought processes which mediate our question and their answer (the stimulus and the response). We do care about the considerations that lead them to the answer and we do expect meaningful communication. Unfortunately, the computer-based drill and practice programs we have observed do not encourage communication. On the contrary, they especially encourage: 1) pupils to apply almost blind trial and error processes; and 2) teachers to ignore the processes which occur between the question and the answer.

Computer-based drill and practice has become another situation for the pupil where obtaining the correct answer, almost no matter how, is the ultimate goal. The pupils are quite smart, even those who are low-achieving. They will try to find the easiest way to obtain the correct answer. They do not necessarily think of pleasing those of us who are interested in meaningful learning. They even might think that we are pleased no matter how they get the correct answer. Therefore, unless the computer programs are quite sophisticated they will not be able to prevent pupils from guessing and developing ad hoc strategies to obtain the correct answer. Sleeman (1984) reminds us that already in 1973 it was suggested that what he calls intelligent tutoring systems would normally have four distinct data bases:

1. Knowledge of the task domain.
2. A model or a history of the student's behavior.
3. A list of possible teaching operations.
4. Mean-ends guidance rules which relate teaching decisions to conditions in the student mode.

These requirements are quite vague and people might argue whether a given computer system fulfills them or not. But even Sleeman admits that the well-known systems that (so he believes) include those four data bases include them in "a very simplistic form." In the meantime, at least some people feel that the promise of computers in education has not been fulfilled.

M. C. Linn and C. W. Fisher (1983) have written a paper entitled: The Gap between Promise and Reality in Computer Education: Planning a Response." Its opening paragraph states:

> The current gap between the promise of computers in schools and the reality of their use in classrooms is simply too great. Before a national magazine heralds the trend with a cover story such as "Macro-Expectations Micro-Outcomes: Computers Fail School," a concentrated effort is needed to change the situation (1983).

This gap is reflected in the results of a small study in which we compared achievement in math for classes working with one of the computer systems versus classes assigned a math expert for the same cost (Davis, et al., 1985). The results favored the classes assigned a math-expert. We see this as almost trivial considering the drawbacks of the computer systems which have been mentioned here.

It is clear that software should be much more sophisticated. It is also clear that there is no inexpensive way to develop it. Sleeman (1984) mentioned the ratio 100/1 between preparation hours to computer-assisted instruction hour. We were told by a project director of a different ratio which is 600/1 (his programs make much use of graphics).

We were also taught a long time ago that the economic factors are most dominant in human development. Combining all these, one could be a little skeptical about the chances that (what Sleeman calls) intelligent tutoring systems would become really intelligent. However, we feel that it is important to try, and present some of our suggestions in Chapter 10.

9. PUPIL'S ATTITUDES

In addition to observing behavior in computer rooms, we decided to assess pupil attitudes towards the drill and practice programs. These are no less important in providing information for future development. Unfortunately, attitudes are difficult to measure and we were faced with a serious social desirability problem (Rosnow and Davis, 1977) as well as difficulties of self-expression in young children. We were concerned that young children would not be able to distinguish between their own attitudes, the attitudes of the other pupils and those expected of them or reinforced by the teacher. Therefore, we decided to examine sixth grade children, only, and to make the questionnaire as short and simple as possible.

A preliminary questionnaire included ten items, most of which were structured. We attempted to ask questions which would not be leading. For example, one of them asked if the pupil wished to work with the computers more, less or the same amount during the week. This version of the questionnaire was tested in a number of schools using Toam and Mashov. The analysis of replies to structured items showed virtually no variation among respondants; they all replied favorably to all the questions. However, on the two open ended questions (Is there something that you especially like about the computer? and Is there something that you especially do not like about the computer?) the children's comments varied greatly and, in our judgement, more accurately reflected their true attitudes. It was then decided that the questionnaire should include only these two questions with the wording slightly changed.

At the top of the questionnaire appeared, 'What I like about the computer' and in the middle of the page appeared, 'What I do not like about the computer.' The children were asked to write whatever they wanted, or nothing. No prompting or examples of what to write were given, and an

observer was present to prevent prompting by the teacher.* Due to budget restrictions only one sixth grade class was sampled in each school. In all, 19 classes provided 462 completed questionnaires for the analysis.

The prose nature of the responses made analysis difficult. Children varied greatly in the detail, clarity, and over all length of their comments. A number of arbitrary decisions were necessary to define a single comment. For example, we decided to give equal weight to all comments (that might have differed in intensity or specification). The comment "I like math drill" was counted as one comment and "I like addition exercises. I like division exercises. I like multiplication exercises" were counted as three comments. In general, most of the children wrote 4 or less comments. In order to reduce the effect of differences in children's detail, we simply coded each questionnaire into one of three broad categories: most comments were positive, most comments were negative, and the number of positive and negative comments were equal.** Correspondingly we refer to three groups of children: positively oriented, negatively oriented, and neutral in orientation. In the latter group we also included 4 children (out of 462) who made no comments at all.

In Table 1 we present percent of children according to orientation (positive, neutral, negative) for each of the three systems. In Figure 1 we present the same data for system and type of school combinations.

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* Two Mashov schools where due to a mistake an observer was not present were excluded from the sample.

** Another analysis was done by one of our students, Yaron Meir. He counted the number of positive and the number of negative comments and took the difference as the dependent variable. Similar results were obtained.

Table 1: Pupil orientation according to system and school-type. (summarized over system)

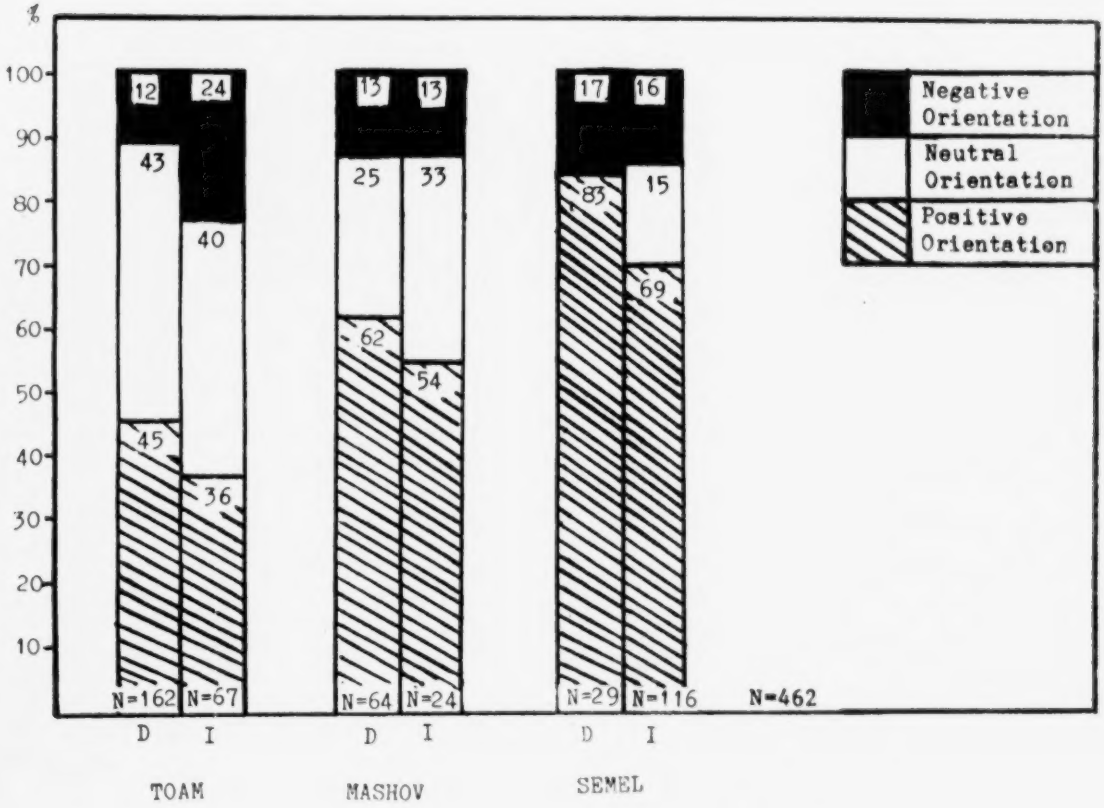
ORIENTATION / SYSTEM	PERCENT POSITIVE	PERCENT NEUTRAL	PERCENT NEGATIVE	N (462)
TOAM	42	42	16	229
MASHOV	60	27	13	88
SEMEL	72	12	16	145

It can be seen that **Semel** children were most likely to be positively oriented (72%) followed by **Mashov** (60%) and lastly by **Toam** (42%). Relatively few children were negatively oriented (13% to 16%). **Toam** stands out in terms of the percent of neutral children (42% versus 27% in **Mashov** and 15% in **Semel**).

We feel that the relatively high percent of positively oriented children in **Semel** was mainly a result of the inclusion of mathematical games. The relatively high percent of children with no opinion one way or the other in **Toam** was, in our opinion, a result of the tight, uniform structure in which material was presented, which was neither exciting nor confusing. As for **Mashov** the percent of positively oriented children is higher than in **Toam**, possibly because of the greater variety and color in presentation or the lack of time limit. It is not as high as **Semel**, possibly because of the complexity of presentation and confusing hints (see Chapter 8). These explanations are consistent with our observations of children working in computer rooms.

It can be seen in Figure 1 that in all systems, the percent of positively oriented children was lower in integrated schools. We raise three possible reasons for this. It could be that children from disadvantaged schools enjoyed fewer successful learning experiences in their regular classrooms in general and therefore the positive reinforcement received from the

Figure 1: Pupil orientation according to system and school-type (summarized over system and school-type combinations)



D = disadvantaged schools I = integrated schools

computer was more meaningful for them. (It should be noted that in Chapter 7 we found no consistent differences in percent of correct responding in disadvantaged and integrated schools). Another reason could be that the individualized attention and/or the structured and concrete skills practiced were more meaningful to children of disadvantaged background. Thirdly, we assume that computers were more likely to be present in the homes of children in integrated schools than in the homes of children in disadvantaged schools. Consequently, the children in these schools would be less awed or impressed with the computer room.

Selected comments

We present here selected pupil comments from the questionnaires. They are not necessarily representative of the responses but were selected as interesting or insightful comments. The comments were translated but not edited.

- I don't like when I guess problems that I don't know and in the end the teacher yells at me because of the progess report.

- I think that the work on the computers help us very much in our studies and we understand more.

- I like the English and reading lessons because in these lessons I don't have to hurry and don't make many mistakes and the problems don't change fast and that's why I like them.

- I like to sit with the computer and get problems better than the problems the teacher gives in class.

- There are things that I don't understand, even when I get 'well done' from the computer.

- I don't like when I look for a trick for answering and don't understand why I answered like that.

- Sometimes I'm given problems that I didn't learn and if I make a mistake he then writes me a bad comment, and that really bugs me because I'm not to blame that sometimes the computer gives me problems that I didn't learn.

- More than anything, I like the games in math or English, because it transferes the material to the head and it sticks more, because children like to play games and through the game the material is transferred to the head better and sticks.

- Sometimes I don't feel like working and I don't care or I make mistakes on purpose.

- There are children who make a lot of mistakes, and rightfully so, because the material they haven't learned, and they can't learn the material from the computer, and can answer only like a parrot and then it isn't worth it.

- In division you have to write the ones first and then the tens, and before they had me write first the tens.

- I like to type on the keyboard. I feel like I'm a clerk working and this gives me a good feeling.

- I like all the lessons because the computer asks me if I want to continue or not.

- At first I really liked the computer but slowly, slowly it gets tiring.

- I don't like that it doesn't talk and I make a mistake and he doesn't understand me so much.

- They don't let me continue when I feel like it.

- There are a lot of subjects, and that way when one subject bores me there are other subjects.....they keep a person from getting bored.

- I love math and English but the computers don't advance me so much in my studies.

- I don't like that the teacher doesn't allow me to play games after I finished the program.

- I would prefer games that weren't mathematical, so that a child can have fun and break the routine of studying math or other subjects.

- I don't like the cops and robbers game, because it changes the rules all the time.

- If there is something boring it's not possible to change it without it being written in the grade.

The above analyses reinforce the view that games are effective in promoting positive attitudes. The fact that less than half of the Tom children were positively oriented indicates that at some point children may be "turned off" by the repetitive, unembellished format in which problems are presented.

10. SUMMARY AND DISCUSSION

1. SYSTEM UTILIZATION AND OPERATION

In **Mashov, Semel and Toam**, we found that computer rooms were being used most of the time during school hours. However, one school in our sample cut the number of hours drastically due to budgetary problems. We encountered a school (outside our sample) which closed its computer room because the service contract could not be paid. We expect that if the budgetary squeeze continues, we will see an increase in these phenomena. This is especially true if, indeed, more than one person is needed in the computer room as many schools seem to feel. The pupil-adult ratios we observed in computer rooms ranged from 8:1 to 33:1 with the median=12:1 (over the 21 schools). This is quite low and represents a relatively high investment of staff hours per pupil. It should be noted, however, that the staff member may not necessarily have to be a professional teacher. (This is debatable, since we have encountered situations where presence of a math-trained operator was clearly helpful).

It should also be noted that in computer rooms the pupils get individualized treatment (from the computer) which they are unlikely to get in the regular classroom situation. Therefore, the unexpected, relatively high investment in manpower may be worth it. But, in any case it is clear that computers do not yet lead to lower manpower demands, and their future utilization may decrease due to inability to cover manpower costs.

While the three systems examined in detail were found to be well-managed, **Toam** clearly stood out as superior in the technical aspects of system operation. There were virtually no technical problems in the 112 **Toam** lessons we observed. Children did not have to wait as much for new materials or lessons. Also, the element of time limitation in **Toam** led to a greater number of exercises being encountered by pupils. Unfortunately, a clear cut recommendation cannot be given on this basis. The gain in

quantity of exercises and time on-task is not necessarily an indication of greater educational value. This would require further research to answer.

2. WORK PATTERNS

a. Engagement With Others

We examined the percent of time pupils were interacting with the computer, working with auxiliary materials (paper and pencil computations, etc.) and interacting with the teacher or with another pupil.

Toam children were almost always engaged with the computer while **Semel** and **Mashov** children were significantly engaged with auxiliary materials in addition to the computer. There were no strong or consistent differnces according to school-type. In general, sixth graders spent somewhat more time engaged with the computer and less time disengaged in comparison to fourth graders.

b. Time On Task

For percent of time definitely on-task, the results are impressive. In 4th and 6th grade, the percent of time definitely on-task ranged from 81% to 92% in the **Toam** schools, from 77% to 84% in the **Mashov** schools, and from 81% to 89% in the **Semel** schools.

There were no strong or consistent differences among disadvantaged, integrated and advantaged schools. This is an encouraging result since it was expected that children in disadvantaged schools would be less focused. The computer apears to have equalized time on task for disadvantaged and advantaged children. Sixth graders, in general, spent somewhat more time on task than fourth graders.

c. Teacher-Pupil and Pupil-Pupil Interactions

In general, in **Mashov** there were more teacher-pupil task-oriented interactions than in the other systems. This may be a result of the

complexity of presentation compared to the other systems (use of explanations and hints) and somewhat greater emphasis on problems involving mathematical concepts.

There were no strong or consistent differences among school types concerning pupil-pupil interactions. In general, there were more task-orientated pupil-pupil interactions in **Semel** schools.

d. Waiting Time

Toam children virtually never waited compared to 3% to 5% waiting time for **Mashov** and **Semel**. The goal of **Toam** for attaining maximum efficiency in terms of number of problems per minute is clearly reflected here. It is hard to judge whether or not the 3% to 5% waiting time in **Mashov** and **Semel** is 'good' or 'bad'. We did not see any serious differences among the systems in signs of frustration or nervousness. Also there were no complaints of children about waiting too long for computer changes. On the other hand, about 9% of **Toam** children complained about the time limit on problems.

3. REVISION AND CORRECTION OF COURSEWARE

Correction and revision of materials is crucial to the development of sound educational curricula. On the basis of our discussions with the program developers and school personnel, our examination of courseware and our observations in the field and in our computer room, we conclude that **Semel** and **Toam** were relatively problem-free and were very responsive to teachers' comments for correcting or developing courseware. In **Mashov**, on the other hand, we found many mistakes and confusing feedback and hints which should have been corrected or dropped.* Also, **Mashov** lessons end immediately

* In addition to the examples presented in this report, a collection of difficulties and confusions in courseware was organized by one of our students, Tsila Zodkevich. It is based on our own and students' observations and the phenomena found were similar.

after the child's first response after 20 minutes have passed. No feedback is given concerning its correctness. It is clearly undesirable to present a pupil with a problem, have him respond and not to give him feedback. This serious flaw should have been corrected, yet **Mashov** chose to 'freeze' the program and, as far as we can tell, the Ministry of Education has not attempted to force correction of this or other serious flaws. It is particularly discouraging that the Ministry of Education has not taken a stronger role in maintaining educational standards. Minimal controls exist, yet, in our opinion, they are not demanding enough, do not affect schools which already have computer systems and only apply to schools who have not yet acquired computer systems. We feel that it is imperative that courseware companies be required to correct and revise materials according to Ministry of Education demands.

Our conclusions concerning **Tapuach** are based only on observations in our computer room. In the first year of operation the translated **Milliken exercise program** was replete with errors and difficulties. For example, some complex English phrases such as "**Not Reduced...**" were not deleted and replaced by Hebrew. Also, we found that the standard Israeli procedure for writing a decimal fraction was not accepted by the program. For example, one-quarter was expected to be entered as ".25" in the American fashion and not as "0.25" in the Israeli fashion. Thus, children who attempted to respond correctly (0.25) according to Israeli procedure could not do so because only three spaces (including the decimal point) were allotted for the answer: .25). It is hard to imagine a more serious educational flaw than one in which a correct response is not accepted. **Tomar** claimed they were limited by copyright and could only translate but not change the content of the program. However, as previously mentioned, Milliken has no knowledge of their materials being translated or being used in Israel. Also, an inspection of recent Milliken programs revealed that the version used by **Tomar** has long since been replaced by improved materials. We do not understand why **Tomar** has not kept up with the changes.

Fortunately, the last year of the study (1984-5) some corrections were made and all feedback on **Tapuach** was in Hebrew, yet many technical bugs remained in the program. For example, sometimes a problem involving the four operations with fractions spanned more than one line and the following appeared on the screen:

2 ÷ 3 + 2 ÷ 3 = 1 1 ÷
3

In addition the symbol " ÷ " is not familiar to Israeli students. Responses to our queries about problems such as this leave much to be desired.

4. INTERNAL EVALUATION

Toam was the only system which systematically collected, analysed and reported data on children's performance (**Semel** did so only during the early development of the math program). The lack of systematic examination of children's performance by the other systems greatly hampers their ability to revise and improve their courseware. Considering the relative simplicity and low cost of collecting and analyzing computerized data, not to do these is simply unacceptable.

The **Toam** analyses carried out in a quasi-experimental design indicated strong achievement gains (Osin, 1981). However, the children were tested on **Toam**, using the standard **Toam** format. This greatly reduces the importance of the finding, since in most problems **Toam** provides cues such as partial-product alignment. As mentioned previously, incorrect partial-product alignment is a common mistake (see Reisman, 1972). Since it cannot be made when testing is carried out on **Toam**, it is clear that children's performance on standard tests and in day-to-day mathematics applications will be poorer than their performance on **Toam**. How much poorer remains to be seen since the true effectiveness of any computer can only be

examined using standard classroom formats for presenting problems. Another limit to generalizing results found on Toam is their use of small numbers only (which can be used without the help of paper and pencil).

It is worth mentioning here that in an investigation of the system from which Toam was derived Glass (1982) rejected the use of a test similar to that used by Toam. His reasons were similar to those stated above, and they reinforce the view that computer-curriculum specific tests are inadequate for evaluating the effect of computer curricula on achievement. They provide an overly optimistic picture.

5. TEACHERS' UTILIZATION OF COMPUTER REPORTS

All the computer programs examined in this study provide student preformance reports. We only touched the surface of this important, but difficult topic.* However, our strong impression is that most teachers do not (and possibly cannot in present conditions) adequately utilize the information provided by computer reports.

We noted one interesting phenomenon which points to lack of utilization of the computer report by teachers. The computer systems allow teachers to set parameters which change aspects of the drill. For example, a teacher can change the difficulty level within a specific strand for a specific student, open or close a strand, etc. The systems differ in the options which are intended to allow the teacher to adapt the drill to the student's needs. However, in all cases we found that teachers make little use of options to set parameters and most prefer to "let the computer decide."

One possible reason for this is that the information received lacks diagnostic utility. For example, the specific errors made by a pupil have

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* One of our students, Ruti Sustiel, is looking into this more deeply in the framework of our computer room.

in many cases, important diagnostic value (See for example, Brown and Burton, 1978). Yet, none of the system reports relate to these. At most, the teacher gets the percent correct for a given type of problem. The teachers' ability to utilize this type of information is limited for two reasons:

1) If the computer indicates that a pupil is having difficulty at a specific level the reason for it is unknown. The report is only a starting point; the teacher must find the source of the problem, determine what strategy and teaching materials are needed, not to mention finding time to do so within the classroom schedule.

2) Pupils can arrive at correct answers without understanding the concepts involved. For example, one of the problems we observed was answered correctly by the pupil:

$$\frac{1}{2} + \frac{1}{2} = \frac{?}{2}$$

Yet, when asked to shade half a square, the pupil was not able to do so. In this instance, we are doubtful of the meaning of his "success" in solving problems of this type.

Another barrier to utilization of information provided by the computer is the predominance of frontal teaching which generally precludes serious individual attention to each child. Some teachers we spoke to expressed frustration when the reports revealed tremendous, unexpected differences in performance among their pupils. Most teachers (including ourselves) like to think that all their pupils have grasped the material, even the quiet ones sitting in the back of the classroom. This is easy to do when information is sparse. The information provided by the systems we investigated is adequate to highlight strong differences among pupils, but inadequate to pinpoint the specific problems.

Unfortunately, even if the feedback had more diagnostic value, the frontal mode of teaching would still make its application impossible for all but the most resourceful teachers. A result of these problems is that some teachers view the computer room experience as separate and independent from the classroom experience of mathematics. This is one of the issues we hope to investigate in the framework of our own computer room.

Finally, we note the interesting possibility of computer drill as one of a range of activities in individualized educational classrooms. As we mentioned, a small number of **Toam** and **Semel** schools are applying this model and may provide a breakthrough in the efficient utilization of the information provided by computers. However, it is clear to us that this will only come about if the information provided by the systems is made to be diagnostically meaningful.

6. FEEDBACK, SELF-CORRECTION AND FRUSTRATION

We examined the "self-correction rate," defined as the percent of children who respond correctly after having answered incorrectly. It was found that self-correction was most likely in **Toam** followed by **Mashov**, which in turn was followed by **Semel**. A result in this direction was to be expected since **Toam** provides much more explicit feedback than does **Mashov**, which in turn provides more hints and prompts than **Semel** (See section - Overview of Systems). However, a different explanation may be possible; it may be that the systems were presenting different kinds of problems, e.g. an emphasis on fractions in one system versus an emphasis on whole numbers in another. We found that the overriding pattern of problem type was clear and consistent across systems and school types. Most problems were the four operations on whole numbers, followed by concepts and word problems. Also, an examination revealed that self-correction rates did not vary according to problem type. We conclude, then, that the differences observed among systems in the patterns of correct responses were not due to differences in problem types.

In our analysis we found that in disadvantaged schools, less than half of initial mistakes were corrected on the second try and that less than a quarter of second mistakes were corrected on the third try. These percentages of correction seem very low to us and certainly the third try seems of very little use. As we mentioned previously, in light of the minimal feedback provided, the correction procedure is not entirely clear to us. While the first mistake could be a technical one which is discovered in redoing the problem or a conceptual one which is corrected by "restructuring" or "rethinking" the problem, it seems unlikely that such redoing, restructuring or rethinking would occur on the third try. We think that guessing is particularly encouraged at this stage. In addition to this, the low correction rate on the third try is undesirable on behavioral grounds as it provides another failure experience for 70 to 80 percent of the children who get to this point.

In our observations we have noted signs of frustration resulting from failure: random striking of keys on the second and third tries after an initial failure, entering the same mistake more than once, and failure to even look at the correct answer when it is presented by the computer following several incorrect responses. While we found it difficult to document the rate of occurrence of these behaviors it is clearly not negligible and, in our opinion, is a direct result of the insensitivity of the systems to the specific meaning of children's responses.

7. FINAL COMMENTS AND SUGGESTIONS

It is clear that, in general, children worked diligently and were satisfied with their experience in computer rooms. There is no doubt that the computer has succeeded in increasing the time on task for disadvantaged children. We attach great importance to the fact that children in disadvantaged and integrated schools were similar in most measures of task orientation and self correction.

But, however gratifying it is to see children sitting quietly and working, this, in itself, is not enough. The systems we have observed provide only a start toward developing educationally effective computer curricula. They are largely hit or miss in their analysis of pupil responses and in their provision of feedback to both teachers and pupils. They tend to be rigid in their structuring and phrasing of questions which allow children to successfully utilize surface cues to get correct answers. Together, these encourage guessing strategies which preclude learning with understanding.

What can be done to improve existing programs?

A) The Ministry of Education should adopt a policy which obligates courseware developers to correct mistakes immediately. Concretely, both **Mashov** and **Tapuach** should correct their technical problems. A possible long range plan is to require curricula developers to post a bond which would be used to pay for necessary corrections.

B) The computer reports provided by the systems on student performance have little diagnostic utility. This is because no information is given on specific mistakes made by pupils. An effort should be made to store and summarize this information. It is interesting to note that the **Mashov** system does in fact store students responses which can be printed out for the teacher. The developers of **Mashov** are to be commended for attributing importance to this option. Unfortunately, this option does not work in reality. Once a regular progress report is printed, the students answers are erased from the computer's memory. It is not logical to expect that a teacher would ask for specific pupil responses before receiving the report.

C) Opportunities for non-constructive guessing should be reduced. On the basis of the low self correction rates, we recommend that the third opportunity to answer be dropped altogether. The second opportunity to answer is probably useful in most cases. However, even here the correction

rate is too low. Presumably better feedback will remedy this, but it is worth considering the possibility of providing the answer and explanation after the first try for items with very low correction rates.

Another opportunity for guessing is provided by allowing children to advance to problems not yet covered in class. Although we have not observed this in depth, it seems clear to us, a priori, that guessing on the basis of number, verbal, and surface cues will be most prevalent here. Also, possible negative effects are more serious, since mistaken conceptions are less likely to be corrected in class. We suggest, therefore, that children not be permitted to advance to topics not yet covered in class. We realize that there may be exceptions to this: e.g., particularly bright children could move ahead in some topics; some children may have learned a topic in an alternative framework. However, most children, especially those in disadvantaged schools, should not be allowed to drill on material not yet covered in class.

The tendency to guess is probably increased when the child is forced to provide an answer to each question. We feel that the possibility of allowing the child to answer: "I don't know" instead of guessing should be examined. Information on where this occurs would provide more definitive information to the teacher and reduce the number of opportunities for answering correctly for the wrong reason. We feel that adoption of these three recommendations would go far in reducing non-constructive guessing.

D) All systems except for **Tapuach** quickly erased incorrect responses from the screen. This, we feel, reduced their feedback value (see Holland and Skinner, 1961; Bardwell, 1981). We also observed indications that at times in **Toam**, the child never saw his incorrect response because it was erased so quickly. This could easily lead to confusion since the child could attribute the error message to his mistyping the correct answer as well as to his answering incorrectly. We recommend that incorrect answers remain on the screen for a longer period of time or until the child presses 'return.'

E) There is no doubt that it is easy to provide simple "correct-incorrect" feedback for every question. This is much more easily done than considering the range of possible responses of children and constructing appropriate feedback for all of them. Also, examination and revision of feedback will almost certainly be required in the latter case and not in the "correct-incorrect" mode. As a result, marketing pressures have led courseware developers toward the simple "correct-incorrect" feedback model. We hope that continued experience and sound pedagogical reasoning will demonstrate the inadequacy of this approach.

It is not surprising, then, that in the programs we investigated, the feedback is far too simplistic and at times misleading. On the same screen containing the feedback "incorrect, the answer is _____," it is possible in many cases to provide a step by step description of a correct procedure for solving the problem. It is also possible to provide comments which help convey the intention of the exercise. For example, consider the sequence:

(35:5) X 5=
(65:5) X 5=
(40:5) X 5=
(45:5) X 5=

The intention, of course, is that the pupil notice that division by 5 and multiplication by 5 cancel each other. In many cases we observed that the pupil calculated the result of the division by 5 and then multiplied by 5. The final results were correct, but the point of the exercise was not conveyed to the child. Simple feedback for a correct response might have been: "Great, you got the correct answer, I hope you noticed that the multiplication by five and the division by five cancel each other. This saves a lot of work."

We feel that the systems we observed could be greatly improved by the addition of response-specific feedback. We are encouraged that Semel is working in this direction. Mashov's attempt to utilize response-specific

feedback and hints is to be commended. However, failure to follow-up for correction and improvement greatly reduced the effectiveness of the program.

F) More flexibility is needed in the use of prompts. As we saw, Toam used prompts such as partial-product alignment extensively while the other systems generally did not. Prompting is probably helpful in the early stages of learning. But, its continued use in later stages may create reliance on it and provide an overly optimistic view of children's ability to solve that type of problem when it is not prompted. We recommend that prompting be utilized but that it gradually be dropped as the child progresses.

G) We examined students attitudes towards their experience with the computer drill and practice. Based on their answers to a questionaire students were catagorized into one of three groups: positive, neutral and negative orientation toward the experience.

The large difference between Semel and Toam in percent of children who were positively oriented toward their computer room experience is of great interest (72% versus 42% respectively). Toam is highly regimented, children are timed and the material is presented in a repetitive, unembellished format. On the other hand, Semel includes some math exercise in a game format in addition to straight drill. We feel that this is one reason for the difference in attitudes: The game not only provides variety but also an exciting context in which the children practice their math skills.

It is interesting to note that little difference was found between the systems on percent of time on task. On the basis of this one might conclude that the inclusion of a game influenced attitudes but not motivation. However, the frameworks we investigated were too restrictive to allow meaningful investigation of motivation: Students did not control

how long they worked with the programs and the students were generally familiar with only the computer system used in their school. If not for these two limiting factors, it would be possible to more clearly examine student motivation as a function of program type. This would be done on the basis of their choice of program as well as the time spent working with it. Our observations lead us to hypothesize that the above examination would show a preference for **Semel** compared to **Toam**. This is also based on the research literature where the issue of drill in a game framework is receiving increasing emphasis. Lepper (1985), for example, has begun to examine the effect of game frameworks on motivation and achievement, as well as the effect of intrinsic as compared to extrinsic motivation on achievement. An example of drill in a game framework is "football" (in hebrew) that was developed at the Curriculum Center of the Ministry of Education and Culture, and which was awarded a prize for outstanding courseware. In any case, student attitudes are important in their own right, and **Toam**, and to an extent also **Mashov**, could improve student attitudes by including drill in game contexts.

H) Our final comment concerns massed (single strand) versus distributed (multiple strand) practice (i.e. giving the same problem-type over and over versus interspersing problem-types). **Toam** is purely distributed; **Semel** is mixed (three to ten problems of the same type are given before changing); **Mashov** is largely massed since it is a series of lessons and **Tapuach** is purely massed since each problem-type takes a complete disk which must be changed before going on to a new topic. Research findings are mixed, but there seems to be a consensus that massed practice is better at the early stages of learning while distributed practice is better for review (Suppes et al., 1968). Our own impressions based on observations in our computer room indicate that, for children having difficulties, massed practice may be better. In addition, for all students we recommend massed practice in the early stages of working with a given problem type. In later stages practice can be distributed among problem types.

Interestingly, the computer systems examined here provide an almost ideal setting for examining issues such as massed versus distributed practice. Children in the same class could be randomly assigned to one of a series of treatments and tested in a true experiment. Unfortunately, as far as we know this capability has not yet been utilized by any of the systems.

The suggestions we have made here should greatly reduce guessing and increase meaningful communication between the computer program and the pupil. Also, we feel suggestions such as these could be introduced at relatively little additional cost in the systems we observed. The extra investment is worth it.

Just prior to the final printing of this report we were informed by **Toam** of implementation of a number of our suggestions in their math drill program and, in addition, in their reading drill program. Also, **Semel** reported implementation of some of our suggestions. We have not heard from the developers of **Mashov** and **Tapuach** concerning changes.

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Tel. 02-882016

School of Education
The Hebrew University of Jerusalem

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